COMBINED SEWER OVERFLOW CONTROL COSTS

AT ONTARIO RAP SITES

SUMMARY REPORT

CH2M HILL ENGINEERING LTD.
Waterloo, Ontario

July 1992

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Report Prepared For:

The Ontario Ministry of Environment and Energy
Water Resources Branch

and

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Wastewater Technology Centre

Report Prepared By:

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DISCLAIMER

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EXECUTIVE SUMMARY

BACKGROUND

Remedial Action Plans (RAPs) are currently being developed for a number of sites in the Great Lakes Basin in accordance with recommendations made by the International Joint Commission, Great Lakes Water Quality Board. These sites, known as Areas of Concern (AOCs), have experienced water quality impairment due to several different causes, and RAPs are being prepared to restore beneficial uses of the water resource. In order to provide information to assist RAP studies, the Ontario Ministry of the Environment and Environment Canada's Great Lakes Cleanup Fund commissioned a study to estimate costs for control of combined sewer overflows. The study resulted in two reports.

1. *Analysis of Combined Sewer Overflow Control Technologies - Kingston and St. Catharines Case Studies.* CH2M HILL ENGINEERING LTD., June 1992.

2. *Combined Sewer Overflow Control Costs at Ontario RAP Sites - Summary Report.* CH2M HILL ENGINEERING LTD., June 1992.

These reports will be published by the Ontario Ministry of the Environment in late 1992. Draft copies are available for review at the Water Resources Branch, Ontario Ministry of the Environment, and at the Great Lakes Environment Office, Environment Canada, Toronto. The following presents an overview of the summary report. For a description of the terminology used in this discussion, see the Glossary at the end of this document.

In several AOCs, a phenomenon referred to as Combined Sewer Overflow (CSO) has resulted in water quality impairment due to the direct discharge of untreated combined wastewater to the receiving waterbody. Only those AOCs with significant areas of combined sewers have been affected. Sections of many Ontario municipalities built prior to 1956 are still serviced by combined sewers. Combined sewers convey both storm and sanitary wastewater flows but are configured in such a way that flows in excess of the downstream pipe flow capacity or the treatment capacity at the Water Pollution Control Plant (WPCP) are discharged directly to receiving waters without treatment. Consequently, CSOs occur during periods of wet weather. The major reason for providing this "relief valve" in the sewer system is to minimize basement flooding and impairment of WPCP treatment capabilities during wet weather. Since 1956, new developments have been serviced with separate storm and sanitary sewers.

There are 17 Canadian Areas of Concern identified by the International Joint Commission, Great Lakes Water Quality Board. These include those areas with RAPs being developed jointly with the United States, at international boundary river locations. Of these, a previous study identified 10 locations with combined sewer overflows.

Two of these were not analyzed in this study. Sault Ste. Marie (St. Mary's RAP) has overflows from the sanitary sewer system which are not, by a strict definition, combined sewer overflows. Collingwood (Collingwood Harbour RAP) has a partly combined sewer system; however, there is no evidence that overflows have occurred. Consequently, the analysis presented below includes the following eight sites.

- Thunder Bay (Thunder Bay)
- Severn Sound (Midland)
- St. Clair River (Sarnia)
- Detroit River (Windsor)
- Niagara River (Fort Erie, Welland and Niagara Falls)
- Hamilton Harbour (Hamilton)
- Toronto Waterfront (Metropolitan Toronto)
- St. Lawrence River (Cornwall)

Other municipalities around the Great Lakes are known to have combined sewer overflows, notably, St. Catharines and Kingston, as well as some inland locations, (for example, London and Peterborough). These locations are not RAP ares, and hence were not analyzed in the summary report. Since two of the locations have completed Pollution Control Plans (St. Catharines and Kingston), they are described in the case study reports used to derive the approach. One other RAP site, Bay of Quinte (Belleville), is also included in the analysis.

CSOs vary widely in terms of both their quality and quantity. CSO events are generally characterized by relatively low flows, however, 25 to 30 percent of events involve large volumes. These events may impair beneficial uses of the water resource and result in curtailed recreational activities such as beach closing.

The receiving water quality impacts of CSO vary depending upon the quality and quantity of the wastewater and the assimilative capacity of the receiving waterbody. Potential water quality concerns resulting from CSOs include:

- Bacteria from faecal material.

- Nutrient enrichment, which can lead to nuisance growths of algae in the receiving waterbody.

- Deposits of contaminated sediments which can lead to degradation of benthic (bottom-dwelling) organisms and restrictions on dredging.

- Toxicity from ammonia, metals and organic compounds present in the wastewater.

- Oxygen depletion potential ("oxygen demand") of the wastewater, which can lead to oxygen deprivation of the organisms in the receiving waterbody.

- Aesthetic impacts from floatable matter.

The volume of wet weather flow which reaches combined sewers is determined by three factors:

- Amount of precipitation.

- Drainage area of the combined sewer.

- Fraction of precipitation which does not permeate the surface it falls on and is collected by the combined sewer, known as the runoff coefficient (symbol: Cv).

These runoff flows are distributed over the year according to the local rainfall characteristics. The amount of runoff which actually overflows from combined sewers depends upon the configuration of the system and can be estimated through mathematical modelling.

Once collected, runoff from combined sewer areas mixes with sanitary flows and reaches a flow regulator at some point upstream of the WPCP, referred to as the central treatment facility. The purpose of the flow regulator is to regulate flow to the central treatment facility in order that it may function adequately. Uncontrolled peak flows will not be fully treated and may impair the treatment capabilities of the plant, which may require as long as days or weeks to recover. When flow at the regulator exceeds that which the interceptor sewer or the plant can handle, a combined sewer overflow (CSO) occurs. In most instances, this overflow is discharged directly and can result in the damage to the receiving waterbody noted previously.

Efforts to control CSOs have focused on combinations of four possible technologies:

1. Sewer separation by provision of either a new storm sewer or a new sanitary sewer. Many municipalities practice partial separation, by connecting road drains to storm sewers. Private property connections, (i.e. foundation drains and roof downspouts), are often difficult to disconnect from the combined system. Hence, separated sanitary systems often continue to have overflows. Sewer separation also leaves the storm sewer discharges uncontrolled. Consequently, while sewer separation has been commonly practised in Ontario, this approach is being reconsidered in light of other options described below.

2. Expansion of the interceptor sanitary sewer and central treatment flow capacity to treat a larger fraction of flows which would otherwise result in CSO.

3. Storage of CSO in order to avoid direct discharge to receiving water. This stored flow can then be redirected to the central treatment facility when capacity becomes available following the wet weather event.

4. Treatment of CSO as it overflows locally in a satellite treatment facility. Such facilities usually focus on physical-chemical treatment of CSO while central facilities generally provide both physical-chemical and biological treatment of both dry and wet weather flows. Disinfection is included in both satellite and central treatment.

The cost analysis carried out for this study was based on combinations of options 3 and 2, (storage and central treatment) and 3 and 4 (storage and satellite treatment). Sewer separation was not analyzed in view of its high cost and limited environmental benefits. For example, analysis conducted during the Kingston and St. Catharines case studies indicated that sewer separation can actually worsen receiving water quality. This can occur when the stormwater collected in the separated storm sewer is of worse quality than the previously combined sewage and it is discharged directly without treatment. In this case, the considerable expenditures involved in a sewer separation program result in degraded rather than improved receiving water quality.

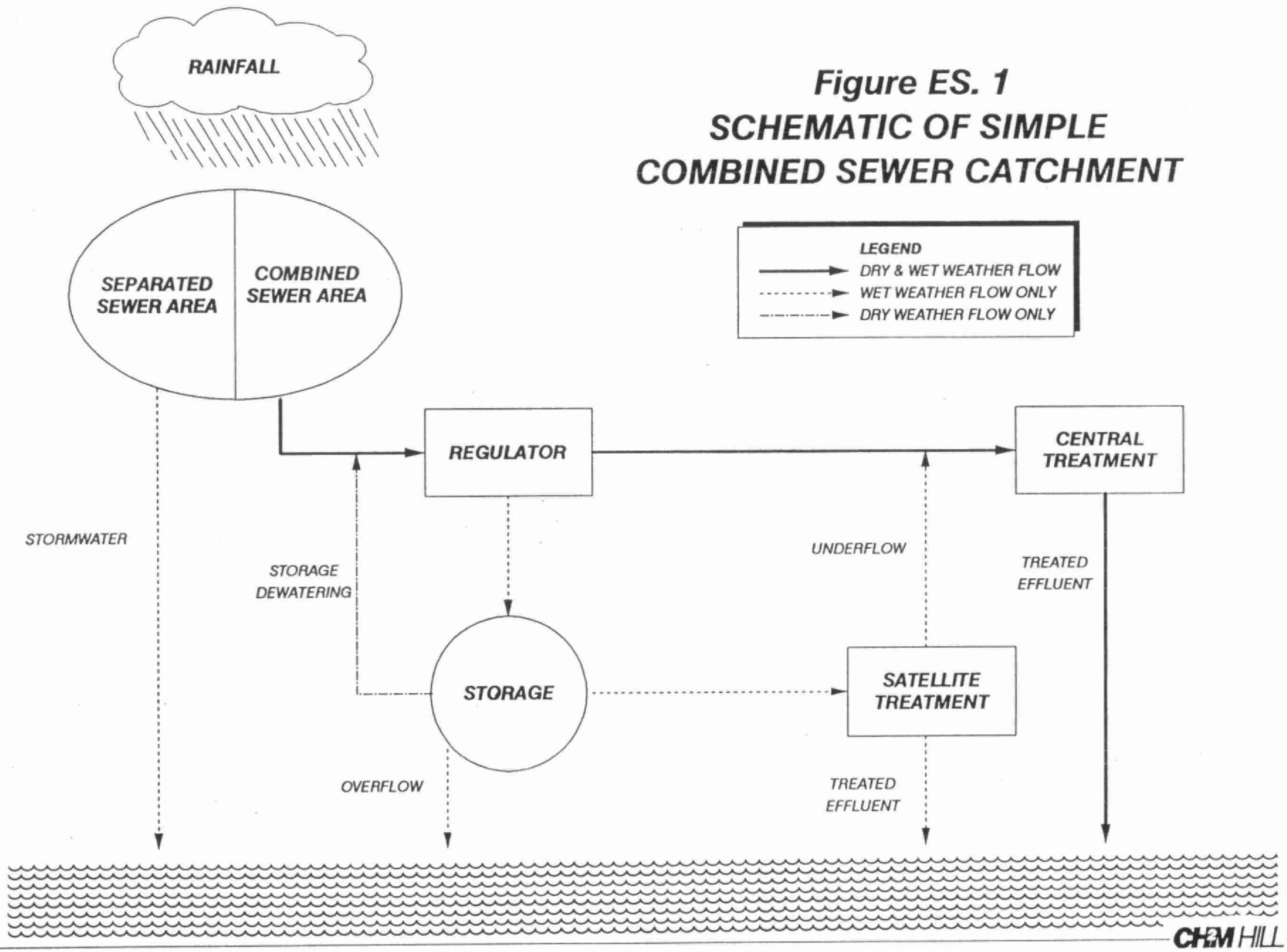
Figure ES.1 is a simplified schematic of a sewer system with some areas serviced by combined sewers, others serviced by separated sewers and with storage and satellite treatment facilities in place. The following paragraphs describe how the system functions.

During a wet weather event, CSO from the regulator flows to the storage tank and then to the satellite treatment facility. The satellite treatment facility also has a limiting capacity, which when reached, results in accumulation of wastewater in the storage facility and possibly eventual overflow to the receiving waterbody. Treated effluent from the satellite treatment facility is also discharged directly to the receiving waterbody. A small fraction of the discharge flow carries the contaminants removed from the treated effluent to central treatment. This stream is known as underflow. The central treatment facility also discharges a treated effluent to the receiving waterbody. Finally, at the end of a rain event, wastewater accumulated in the storage facility is directed to central treatment provided that adequate treatment capacity is available. This measure, known as storage dewatering, is favoured over using satellite treatment largely because pollutant removal efficiencies are generally higher at the central treatment facility.

In summary, there are four sources of discharges to the receiving waterbody:

- Storm water from separated sewer areas.
- Treated effluent from the satellite treatment facility.
- Overflow from the storage facility.
- Treated effluent from the central treatment facility.

Figure ES. 1
SCHEMATIC OF SIMPLE COMBINED SEWER CATCHMENT



In an intense rainfall event, all four sources will be discharging. In a less severe event, the satellite treatment facility will be capable of handling all of the regulator overflow and the storage facility will not overflow. In smaller events, all combined flows will flow through the regulator to central treatment and only discharges from separated areas and the central treatment facility will occur. During periods of no rainfall, the only discharges are those of treated sanitary dry weather flows from the central treatment facility.

The level of CSO control may be measured against several criteria which are related to impairment in the receiving water. Among these are:

- Number of overflow, or "spill", events per year (symbol: Ns). This is a useful control criteria when the problem is acute toxicity of the overflow, or intermittent beach closures due to high loadings of bacteria during overflow events.

- Percent volumetric control, or the yearly volume of wet weather flow which is retained and/or subsequently treated and is not lost as overflow, as a percentage of total yearly wet weather volume (symbol: Cr). This is a good general measure of overall control, related indirectly to the total loadings of all pollutants to the environment. This is best used when total loadings to a large body of water are a concern.

- Percent pollutant control, or the yearly mass of a specified pollutant which is retained and/or subsequently treated and is not directly discharged, as a percentage of total yearly mass in wet weather flow (symbol: Cp). This control criteria is applicable when a specific pollutant is identified as the source of impairment, such as contaminated sediments, bacteria, or phosphorus.

These control criteria may be estimated using mathematical models.

METHODOLOGY

As an alternative to the detailed CSO analysis which is usually undertaken as part of a Pollution Control Planning (PCP) Study, this study modified an existing model to examine the effectiveness and associated costs of various CSO control options for each RAP municipality. While the cost estimates developed using this methodology may not be as accurate and precise as those developed using a more detailed analysis, they do provide valuable information in the preliminary planning process.

The major elements of the methodology used in this study are depicted in Figure ES.2. Essentially, performance analysis is used to determine the amount of storage and/or treatment capacity that is required to meet selected CSO control criteria. The performance analysis also depends on a system description of the sewer catchment of interest and appropriate precipitation data.

Several combinations of technologies may achieve the same level of CSO control and therefore cost optimization is required to determine the least cost solution. An existing model of CSO control, known as the Extended Statistical Urban Drainage Simulator, or EXSUDS, was modified somewhat to provide performance analysis and cost optimization appropriate to this study.

EXSUDS has important advantages over other models of CSO control. These include:

- Shorter computational time, allowing comparison of a large number of alternatives.
- Ability to analyze CSO problems on a gross, system-wide basis without resorting to detailed Pollution Control Planning Analysis.

It is also important to note that for these same reasons, EXSUDS does not incorporate specifics with respect to system features and controls. The major simplification made in the system description for this analysis of Ontario RAP sites was that entire municipalities were considered as single catchment areas for the purposes of performance analysis, with characteristics of the catchment area and drainage system averaged over the entire area. For example, the value of the volumetric runoff coefficient was selected to reflect the entire urban drainage area that was being modelled, including all catchments and all separated and combined areas. Thus, the mathematical model accounts for pollutant loading from separate sewers by modelling them as equivalent combined sewers and an effective combined sewer area is used. Flow regulator capacity was assumed equal to the WPCP wet weather treatment capacity since all catchments were considered as one catchment feeding the WPCP.

Least cost solutions for the following two combinations of technologies were sought:

- Storage - central treatment
- Storage - satellite treatment - central treatment

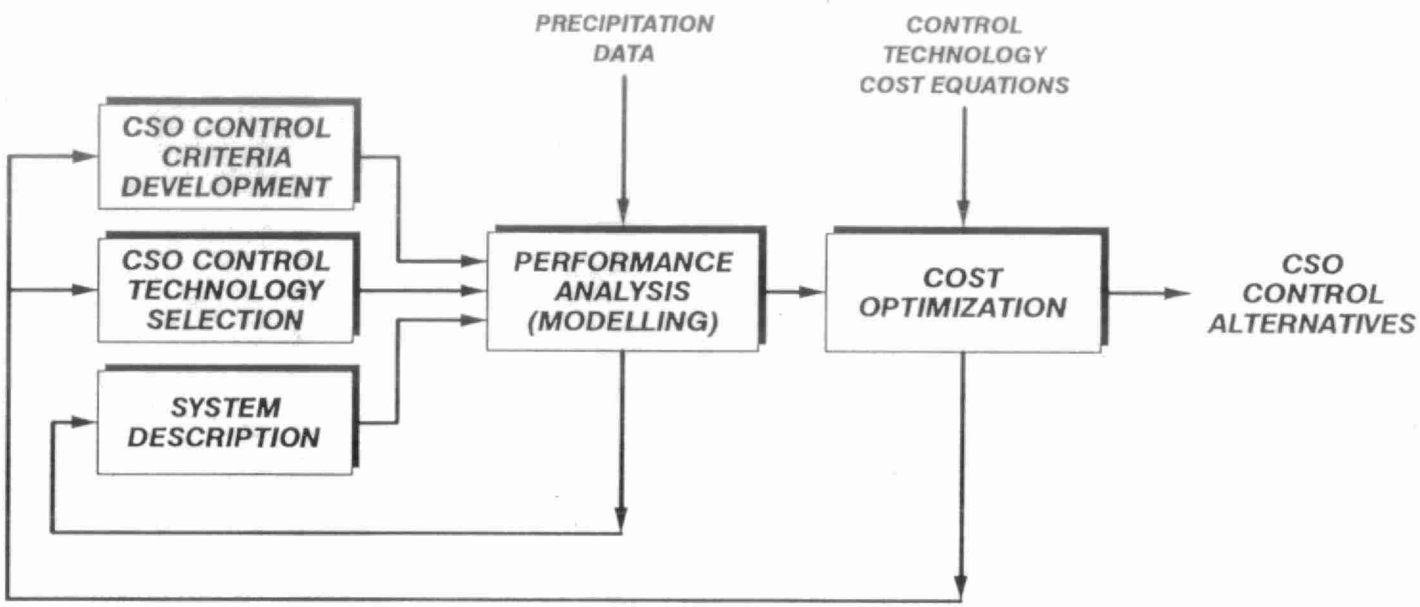


Figure ES. 2
ANALYSIS METHODOLOGY DESCRIPTION AND DEVELOPMENT

EXSUDS performs the following calculations:

- The minimum time elapsed between rain events in order to consider them as separate events is defined and input rainfall data are summarized statistically to give the mean and variance for the following variables:
  - Storm volume
  - Storm duration
  - Storm intensity
  - Number of rain events.

- Rainfall statistics, the system description and information on costs of the various technologies are used in mathematical equations which calculate the least cost combination of storage and treatment technologies to reach the desired level of control.

Two case studies were undertaken to compare results of modified EXSUDS modelling with that performed using the STORM model as part of detailed Pollution Control Planning (PCP) for the Cities of Kingston and St. Catharines. Comparison of performance analysis results were favourable and cost estimates were well within an order of magnitude of one another. These results provided guidance in the interpretation of modelling results for the Ontario RAP sites.

Data describing the RAP municipalities was gathered in order to meet input data requirements. Raw data regarding land use, separated and combined sewer area and WPCPs for each municipality are summarized in Table ES.1. These data were used to estimate input data which are summarized in Table ES.2. Other pertinent assumptions are summarized in Table ES.3. This study also examined CSO control criteria involving two pollutants of interest, suspended solids (SS) and fecal coliforms (FC). Pollutant removal efficiencies for the WPCPs and satellite treatment systems considered in this study are summarized in Table ES.4.

TABLE ES.1
ONTARIO RAP MUNICIPALITIES CHARACTERISTICS

Municipality	CATCHMENT PARAMETERS							WPCP DATA			
	Area by Land Use				Area by Sewer Type			Average Annual DWF	WPCP Design Capacity	Plant Type	Plant Name
	Res. (ha)	Comm. (ha)	Indust. (ha)	Open (ha)	Total (ha)	Comb. (ha)	Separated (ha)	(m3/d)	(m3/d)		
Thunder Bay	2,030	177	711	772	3,690	830	2,860	78,130	109,100	P	THUNDER BAY WPCP
Midland	316	31	111	104	562	231	331	11,350	13,680	S	MIDLAND WPCP
Sarnia	1,600	160	1,090	350	3,200	540	2,660	35,640	65,910	P	SARNIA WPCP
Windsor-East	1,950	149	496	110	2,705	260	2,445	37,720	36,360	S	LITTLE RIVER WPCP
Windsor-West	5,110	391	1,300	294	7,095	2,100	4,995	117,510	163,650	P	WESTERLY WPCP
Fort Erie (Anger Ave.)								10,690	16,360	S	ANGER AVE. WPCP
Fort Erie (Crystal B.)								4,250	3,880	S	CRYSTAL BEACH WPCP
Fort Erie Total	432	94	95	1,019	1,640	57	1,583	14,940	20,240	S	
Niagara Falls	1,410	288	531	4,250	6,479	1,600	4,879	56,380	58,180	S	STAMFORD WPCP
Welland	1,040	70	238	1,451	2,799	405	2,394	35,340	45,460	S	WELLAND WPCP
Hamilton	5,646	654	844	4,927	12,071	4,430	7,641	310,570	409,140	S	WOODWARD AVE. WPCP
East York	1,520	53	230	323	2,126	1,596	530	35,460	45,460	S	NORTH TORONTO WPCP
Etobicoke	4,973	875	3,672	2,730	12,250	223	12,027	402,850	409,140	S	HUMBER WPCP
North York	9,810	437	3,930	3,510	17,687	134	17,553				
Scarborough	9,500	590	3,340	5,300	18,730	1,440	17,290	179,500	218,200	S	HIGHLAND CREEK WPCP
Toronto	6,800	535	2,380	0	9,715	7,286	2,429	779,020	818,280	S	MAIN WPCP
York	1,610	139	565	0	2,314	1,020	1,294				
Toronto Total	34,213	2,629	14,117	11,863	62,822	11,699	51,123	1,396,830	1,491,080	S	
Belleville	796	74	279	281	1,430	328	1,102	29,250	54,550	P	BELLEVILLE WPCP
Cornwall	1,300	241	298	582	2,421	605	1,816	49,430	54,550	P	CORNWALL WPCP
TOTAL	**55,843**	**4,958**	**20,110**	**26,003**	**106,914**	**23,085**	**83,829**	**2,188,030**	**2,542,140**		

References:

Catchment Data: Schroeter & Associates, 1991. Loadings of Toxic Contaminants from Urban Nonpoint Sources to the Great Lakes from Ontario Communities. Volume II - Appendices (6).
WPCP Data: Water Resources Branch, Ontario Ministry of the Environment. MOE Report on the 1989 Discharges from Municipal Sewage Treatment Plants in Ontario (7).

Notes:

1: P = Primary, S = Secondary
2: Fort Erie: Stevensville/Douglastown not included
3: Belleville: Peak Plant Capacity taken as 163,500 m3/d primary clarifier

TABLE ES.2
DERIVED INPUT DATA SUMMARY
ONTARIO RAP MUNICIPALITIES

Municipality	CATCHMENT PARAMETERS				TREATMENT PARAMETERS		
	Effective Area (ha)	Runoff Coefficient			Net Plant Capacity for WWF (m3/d)	Net WWF Treatment Rate (mm/hr)	Plant Name
		Comb.	Separated	Overall			
Thunder Bay	1,273	0.323	0.050	0.111	194,620	0.637	THUNDER BAY WPCP
Midland	281	0.332	0.050	0.166	22,850	0.339	MIDLAND WPCP
Sarnia	889	0.381	0.050	0.106	129,135	0.605	SARNIA WPCP
Windsor-East	598	0.362	0.050	0.080	53,180	0.371	LITTLE RIVER WPCP
Windsor-West	2,791	0.362	0.050	0.142	291,615	0.435	WESTERLY WPCP
Fort Erie (Anger Ave.)					30,210		ANGER AVE. WPCP
Fort Erie (Crystal B.)					5,450		CRYSTAL BEACH WPCP
Fort Erie Total	455	0.199	0.050	0.055	35,660	0.327	
Niagara Falls	2,862	0.193	0.050	0.085	89,070	0.130	STAMFORD WPCP
Welland	948	0.221	0.050	0.075	78,310	0.344	WELLAND WPCP
Hamilton	5,956	0.250	0.050	0.124	712,280	0.498	WOODWARD AVE. WPCP
East York	1,681	0.311	0.050	0.246	78,190	0.194	NORTH TORONTO WPCP
Etobicoke	1,937	0.351	0.050	0.055	620,000	1.334	HUMBER WPCP
North York	2,825	0.326	0.050	0.052			
Scarborough	4,338	0.298	0.050	0.069	366,000	0.352	HIGHLAND CREEK WPCP
Toronto	7,601	0.385	0.050	0.302	1,266,680	0.694	MAIN WPCP
York	1,187	0.386	0.050	0.198			
Toronto Total	19,363	0.334	0.050	0.103	2,330,870	0.502	
Belleville	496	0.328	0.050	0.114	134,250	1.127	BELLEVILLE WPCP
Cornwall	895	0.313	0.050	0.116	86,945	0.405	CORNWALL WPCP
TOTAL or AVERAGE	36,806	0.300	0.050	0.106	4,194,445	0.477	

Notes:

1: Effective Area is the effective combined area, or the total area multiplied by the ratio of overall to combined runoff coefficient.

2: Net WWF treatment rates are treatment capacity divided by the effective area.

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TABLE ES.3
ONTARIO RAP MUNICIPALITIES
MODELLING ASSUMPTIONS

Default Input Data:				
Maximum Depression Storage Capacity (mm):	2			
Ratio of Peak Plant Capacity to Design Plant Capacity:	2.5			
Net Wet Weather Flow Plant Capacity:	(Design Capacity X 2.5) - Dry Weather Flow			
Runoff Coefficient for Pervious Areas:	0.05			
Runoff Coefficient for Impervious Areas:	0.90			
Land Use Parameters:	Percent Impervious		Cv	
	Combined Areas	Separated Areas	Combined Areas	Separated Areas
Residential	31%	0%	0.31	0.05
Commercial	62%	0%	0.58	0.05
Industrial	58%	0%	0.55	0.05
Open Space	4%	0%	0.08	0.05

TABLE ES.4
ONTARIO RAP MUNICIPALITIES
POLLUTION CONTROL PERFORMANCE DATA

Municipality Name	*Plant Name*	*CENTRAL WPCP REMOVAL EFFICIENCIES*	
		SS [%]	*FC [%]*
Thunder Bay	THUNDER BAY WPCP	67%	99.99%
Midland	MIDLAND WPCP	96%	99.99%
Sarnia	SARNIA WPCP	86%	99.99%
Windsor-East	LITTLE RIVER WPCP	97%	99.99%
Windsor-West	WESTERLY WPCP	80%	99.99%
Fort Erie (Anger Ave.)	ANGER AVE. WPCP	67%	99.99%
Fort Erie (Crystal B.)	CRYSTAL BEACH WPCP	78%	99.99%
Fort Erie Total		72%	99.99%
Niagara Falls	STAMFORD WPCP	83%	99.99%
Welland	WELLAND WPCP	88%	99.99%
Hamilton	WOODWARD AVE. WPCP	96%	99.99%
East York	NORTH TORONTO WPCP	91%	99.99%
Etobicoke	HUMBER WPCP	94%	99.99%
Scarborough	HIGHLAND CREEK WPCP	89%	99.99%
Toronto	MAIN WPCP	93%	99.99%
Toronto Total		92%	99.99%
Belleville	BELLEVILLE WPCP	92%	99.99%
Cornwall	CORNWALL WPCP	84%	99.99%

Municipality Name	*Plant Name*	*ASSUMED SATELLITE TREATMENT REMOVAL EFFICIENCIES*	
		SS [%]	*FC [%]*
Thunder Bay	THUNDER BAY WPCP	30%	99.99%
Midland	MIDLAND WPCP	30%	99.99%
Sarnia	SARNIA WPCP	30%	99.99%
Windsor-East	LITTLE RIVER WPCP	30%	99.99%
Windsor-West	WESTERLY WPCP	30%	99.99%
Fort Erie (Anger Ave.)	ANGER AVE. WPCP	30%	99.99%
Fort Erie (Crystal B.)	CRYSTAL BEACH WPCP	30%	99.99%
Fort Erie Total		30%	99.99%
Niagara Falls	STAMFORD WPCP	30%	99.99%
Welland	WELLAND WPCP	30%	99.99%
Hamilton	WOODWARD AVE. WPCP	30%	99.99%
East York	NORTH TORONTO WPCP	30%	99.99%
Etobicoke	HUMBER WPCP	30%	99.99%
Scarborough	HIGHLAND CREEK WPCP	30%	99.99%
Toronto	MAIN WPCP	30%	99.99%
Toronto Total		30%	99.99%
Belleville	BELLEVILLE WPCP	30%	99.99%
Cornwall	CORNWALL WPCP	30%	99.99%

References:

Water Resources Branch, Ontario Ministry of the Environment. MOE Report on the 1989 Discharges from Municipal Sewage Treatment Plants in Ontario

Notes:

Satellite Treatment: Vortex Separator with Disinfection by Chlorination/Dechlorination

RESULTS

EXISTING LEVELS OF CSO CONTROL

Table ES.5 summarizes existing levels of CSO control. The range in these values is accounted for by the differences in the sewer systems, treatment rates and treatment efficiencies among the various municipalities.

The control levels are reasonably narrowly distributed and range from approximately 32 percent to 71 percent volumetric control with the preponderance of results in the 40 percent to 60 percent volumetric control range. The corresponding annual overflow frequencies range from a low of approximately 20 events to in excess of 50 events with the majority of municipalities clustered in the 30 to 40 event range.

Percentage pollution controls for suspended solids and fecal coliforms follow a similar pattern but reflect the combined effect of volumetric capture and differing process removal efficiencies among the various WPCPs (as documented in Table ES.4).

TABLE ES.5
ONTARIO RAP MUNICIPALITIES
ESTIMATES OF EXISTING LEVELS OF CSO CONTROL

Municipality	Percent Volumetric Control	Annual Number of Overflows	Percent Pollutant Control - Suspended Solids	Percent Pollutant Control - Fecal Coliforms
Thunder Bay	58%	28	39%	58%
Midland	43%	39	41%	43%
Sarnia	50%	40	43%	50%
Windsor-East	39%	49	38%	39%
Windsor-West	43%	46	34%	43%
Fort Erie Total	53%	35	38%	53%
Niagara Falls	32%	51	26%	32%
Welland	52%	36	45%	52%
Hamilton	59%	34	57%	59%
Toronto Total	50%	30	46%	50%
Belleville	71%	20	66%	71%
Cornwall	49%	37	41%	49%

STORAGE - CENTRAL TREATMENT

The modified EXSUDS model was used to develop performance and cost information regarding a control alternative involving storage with subsequent central treatment. In this case, the satellite treatment facilities depicted in Figure ES.1 would not be present.

Each municipality was examined separately for a wide range of values for each control criteria. The cost optimal solutions for each level of control, referred to as the expansion paths, are presented in Table ES.6, for percent volumetric control, annual number of overflows and percent fecal coliform removal, and in Table ES.7 for percent suspended solids removal. These latter results are presented separately since not all plants are capable of reaching the control levels of 80 percent, 90 percent and 95 percent used in Table ES.6. This stems from the fact that the ultimate suspended solids removal is limited by the treatment efficiency of the WPCP. All of these tables document similar trends. At lower levels of control, storage solutions are recommended. At higher control levels, a blend of technologies using combinations of storage and treatment are recommended as optimal solutions.

Table ES.8 presents the total capital costs for the recommended central treatment-storage solutions using the Cr, Ns, Cp-FC and Cp-SS control criteria. Aggregate capital cost estimates have been prepared for all municipalities and all control measures except Cp-SS and are plotted as cost-effectiveness curves in Figure ES.3.

Table ES.9 presents these same costs on a per unit effective combined sewer area basis (i.e., $/hectare). Unit area costs are relatively uniform across all municipalities with Midland, Windsor-East and Fort Erie as exceptions. A possible explanation for these higher unit costs is that these are municipalities with relatively small effective combined sewer areas in combination with lower levels of existing control. In these instances, economies of scale are not realized.

Aggregate costs were not prepared for Cp-SS because of the highly variable WPCP efficiencies for solids removal which yield correspondingly different Cp-SS upper limits for each WPCP. This does not permit aggregation of costs for all WPCPs for a given level of control since not all WPCPs may achieve this level. The shaded areas of Table ES.8 indicate where a plant is unable to achieve the levels noted. Costs escalate sharply as this limit is approached, since, in reality, all CSO flows must be treated at the WPCP to achieve this limit.

TABLE ES.6
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
CENTRAL TREATMENT AND STORAGE

Municipality	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
	LEVEL OF VOLUMETRIC CONTROL					
	80%		90%		95%	
Thunder Bay	15,021	0	30,170	0	48,247	0
Midland	4,889	0	9,020	0	17,478	0
Sarnia	18,047	0	33,782	0	55,207	0
Windsor-East	14,591	0	27,030	0	66,139	2,870
Windsor-West	63,077	0	115,547	0	217,140	0
Fort Erie Total	4,004	0	7,644	0	12,194	0
Niagara Falls	39,496	0	79,850	0	137,090	41,213
Welland	9,575	0	18,107	0	29,104	0
Hamilton	54,795	0	114,355	0	184,040	0
Toronto Total	309,808	0	571,209	0	894,571	0
Belleville	2,926	0	8,680	0	14,781	0
Cornwall	13,694	0	25,418	0	42,065	0
Total	549,923	0	1,040,812	0	1,718,055	44,083
	ANNUAL NUMBER OF OVERFLOWS					
	10		3		1	
Thunder Bay	20,877	0	51,175	0	112,024	39,718
Midland	6,688	0	25,318	674	25,318	28,325
Sarnia	28,448	0	70,853	0	103,124	113,081
Windsor-East	22,604	0	64,345	18,658	76,006	96,158
Windsor-West	97,127	0	252,865	60,286	291,939	448,793
Fort Erie Total	6,097	0	14,196	0	30,349	16,380
Niagara Falls	58,671	0	133,369	68,688	174,010	240,408
Welland	14,504	0	34,223	0	69,583	43,229
Hamilton	98,274	0	228,115	0	510,429	257,299
Toronto Total	381,451	0	902,316	0	2,114,440	557,654
Belleville	5,555	0	16,021	0	27,974	0
Cornwall	19,959	0	50,210	0	74,912	75,180
Total	760,255	0	1,843,004	148,306	3,610,107	1,916,225
	LEVEL OF FECAL COLIFORM REMOVAL					
	80%		90%		95%	
Thunder Bay	15,021	0	30,170	0	48,247	0
Midland	4,889	0	9,020	0	17,534	0
Sarnia	18,047	0	33,782	0	55,296	0
Windsor-East	14,591	0	27,030	0	66,079	2,870
Windsor-West	63,077	0	115,827	0	217,698	0
Fort Erie Total	4,004	0	7,644	0	12,194	0
Niagara Falls	39,496	0	80,136	0	137,090	41,213
Welland	9,575	0	18,107	0	29,198	0
Hamilton	54,795	0	114,355	0	184,636	0
Toronto Total	309,808	0	573,145	0	896,507	0
Belleville	2,926	0	8,730	0	14,781	0
Cornwall	13,694	0	25,508	0	42,065	0
Total	549,923	0	1,043,452	0	1,721,325	44,083

TABLE ES.7
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
CENTRAL TREATMENT AND STORAGE
(% SUSPENDED SOLIDS REMOVAL)

Percent Suspended Solids Removal	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
Thunder Bay		
50	10,057	0
60	29,279	0
65	68,233	0
Midland		
80	5,873	0
90	13,460	0
95	29,505	39,115
Sarnia		
70	19,647	0
80	43,739	0
85	106,769	123,749
Windsor-East		
80	16,624	0
90	36,538	0
95	71,939	54,538
Windsor-West		
75	170,809	0
77	252,865	53,587
79	291,939	448,793
Fort Erie Total		
50	1,957	0
60	4,914	0
70	20,020	0
Niagara Falls		
70	50,085	0
80	148,538	82,426
82	175,441	261,014
Welland		
80	19,434	0
85	39,247	0
87	70,152	56,880
Hamilton		
80	70,281	0
90	160,216	0
95	519,959	357,360
Toronto Total		
70	245,910	0
80	466,648	0
90	2,199,637	46,471
Belleville		
70	1,438	0
80	6,448	0
90	23,114	0
Cornwall		
70	16,737	0
80	44,482	0
82	69,810	25,776

TABLE ES.8
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$220,000	$0	$0	$2,660,000	$0	$0	$0	$0	$0	$2,890,000
50	$0	$620,000	$0	$2,020,000	$4,690,000	$0	$6,200,000	$0	$0	$0	$0	$420,000	$13,940,000
60	$920,000	$1,570,000	$3,040,000	$4,160,000	$11,870,000	$750,000	$10,480,000	$1,650,000	$720,000	$28,210,000	$0	$2,770,000	$66,130,000
70	$4,720,000	$2,770,000	$6,760,000	$6,880,000	$20,890,000	$1,950,000	$15,990,000	$3,990,000	$11,800,000	$63,710,000	$0	$5,710,000	$145,160,000
80	$9,820,000	$4,420,000	$11,810,000	$10,680,000	$33,340,000	$3,570,000	$24,000,000	$7,150,000	$26,680,000	$111,530,000	$2,240,000	$9,710,000	$254,950,000
90	$18,060,000	$7,360,000	$20,250,000	$17,690,000	$55,290,000	$6,220,000	$41,880,000	$12,360,000	$50,750,000	$189,530,000	$6,070,000	$16,430,000	$441,900,000
95	$27,480,000	$12,540,000	$31,060,000	$42,530,000	$92,190,000	$9,390,000	$122,100,000	$18,720,000	$78,280,000	$281,500,000	$10,050,000	$25,240,000	$751,090,000
97	$37,160,000	$33,990,000	$49,790,000	$82,960,000	$128,230,000	$13,160,000	$198,550,000	$26,980,000	$106,730,000	$385,660,000	$13,380,000	$42,680,000	$1,119,290,000
99	$85,350,000	$83,130,000	$84,500,000	$187,850,000	$227,850,000	$61,630,000	$392,260,000	$119,560,000	$455,350,000	$1,417,450,000	$21,300,000	$70,390,000	$3,206,630,000
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$680,000	$0	$0	$0	$0	$0	$680,000
40	$0	$0	$0	$1,920,000	$4,690,000	$0	$4,790,000	$0	$0	$0	$0	$0	$11,410,000
30	$0	$1,100,000	$3,720,000	$4,570,000	$13,520,000	$750,000	$10,010,000	$1,650,000	$5,380,000	$0	$0	$2,340,000	$43,040,000
20	$4,150,000	$2,680,000	$8,670,000	$8,220,000	$25,580,000	$2,330,000	$17,380,000	$4,740,000	$20,100,000	$46,860,000	$0	$6,220,000	$146,930,000
10	$12,060,000	$5,320,000	$16,780,000	$14,660,000	$46,140,000	$4,890,000	$31,470,000	$9,740,000	$43,700,000	$120,630,000	$3,720,000	$12,570,000	$321,700,000
5	$20,660,000	$8,810,000	$26,500,000	$25,550,000	$74,740,000	$7,780,000	$87,350,000	$15,470,000	$70,020,000	$201,310,000	$7,610,000	$20,130,000	$565,940,000
3	$28,480,000	$18,990,000	$38,140,000	$66,350,000	$123,770,000	$10,690,000	$155,160,000	$21,450,000	$95,470,000	$275,970,000	$10,790,000	$28,980,000	$874,240,000
1	$66,870,000	$60,810,000	$81,260,000	$162,320,000	$206,470,000	$48,380,000	$330,100,000	$95,530,000	$386,820,000	$911,370,000	$17,610,000	$62,400,000	$2,429,950,000
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$230,000	$0	$0	$2,660,000	$0	$0	$0	$0	$0	$2,890,000
50	$0	$620,000	$0	$2,020,000	$4,690,000	$0	$6,200,000	$0	$0	$0	$0	$420,000	$13,940,000
60	$930,000	$1,570,000	$3,040,000	$4,170,000	$11,870,000	$750,000	$10,480,000	$1,650,000	$730,000	$28,220,000	$0	$2,770,000	$66,170,000
70	$4,720,000	$2,770,000	$6,760,000	$6,880,000	$20,890,000	$1,950,000	$16,000,000	$3,990,000	$11,810,000	$63,730,000	$0	$5,710,000	$145,220,000
80	$9,830,000	$4,420,000	$11,810,000	$10,680,000	$33,350,000	$3,570,000	$24,010,000	$7,150,000	$26,700,000	$111,570,000	$2,240,000	$9,710,000	$255,050,000
90	$18,070,000	$7,360,000	$20,260,000	$17,700,000	$55,320,000	$6,220,000	$41,910,000	$12,370,000	$50,780,000	$189,630,000	$6,080,000	$16,440,000	$442,150,000
95	$27,500,000	$12,570,000	$31,090,000	$42,690,000	$92,370,000	$9,400,000	$122,330,000	$18,740,000	$78,360,000	$281,750,000	$10,060,000	$25,270,000	$752,130,000
97	$37,230,000	$34,110,000	$50,080,000	$83,550,000	$128,760,000	$13,190,000	$199,310,000	$27,060,000	$106,930,000	$386,470,000	$13,400,000	$42,760,000	$1,122,850,000
99	$85,730,000	$83,900,000	$85,010,000	$188,950,000	$228,650,000	$62,080,000	$394,110,000	$120,380,000	$459,190,000	$1,427,140,000	$21,390,000	$70,820,000	$3,227,360,000

TABLE ES.8 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,570,000	$0	$0	$0	$0	$0	$1,570,000
40	$810,000	$0	$0	$480,000	$4,690,000	$310,000	$5,490,000	$0	$0	$0	$0	$0	$11,780,000
50	$6,390,000	$780,000	$2,540,000	$2,360,000	$13,520,000	$1,790,000	$10,390,000	$1,080,000	$0	$13,200,000	$0	$2,500,000	$54,550,000
60	$16,290,000	$1,810,000	$6,640,000	$4,640,000	$25,580,000	$4,040,000	$17,070,000	$3,520,000	$3,810,000	$46,890,000	$0	$5,940,000	$136,230,000
65	$33,590,000												
70		$3,140,000	$12,500,000	$7,590,000	$46,130,000	$12,230,000	$28,400,000	$6,900,000	$16,100,000	$91,240,000	$1,280,000	$11,040,000	
75					$74,740,000								
77					$123,750,000								
79					$206,440,000								
80		$5,110,000	$24,350,000	$11,910,000			$153,890,000	$12,850,000	$33,480,000	$159,260,000	$4,700,000	$24,280,000	
82							$331,700,000					$47,060,000	
85			$79,550,000					$22,980,000					
87								$107,880,000					
90		$9,860,000		$22,090,000					$67,040,000	$572,820,000	$13,560,000		
95		$72,320,000		$106,310,000					$431,220,000				

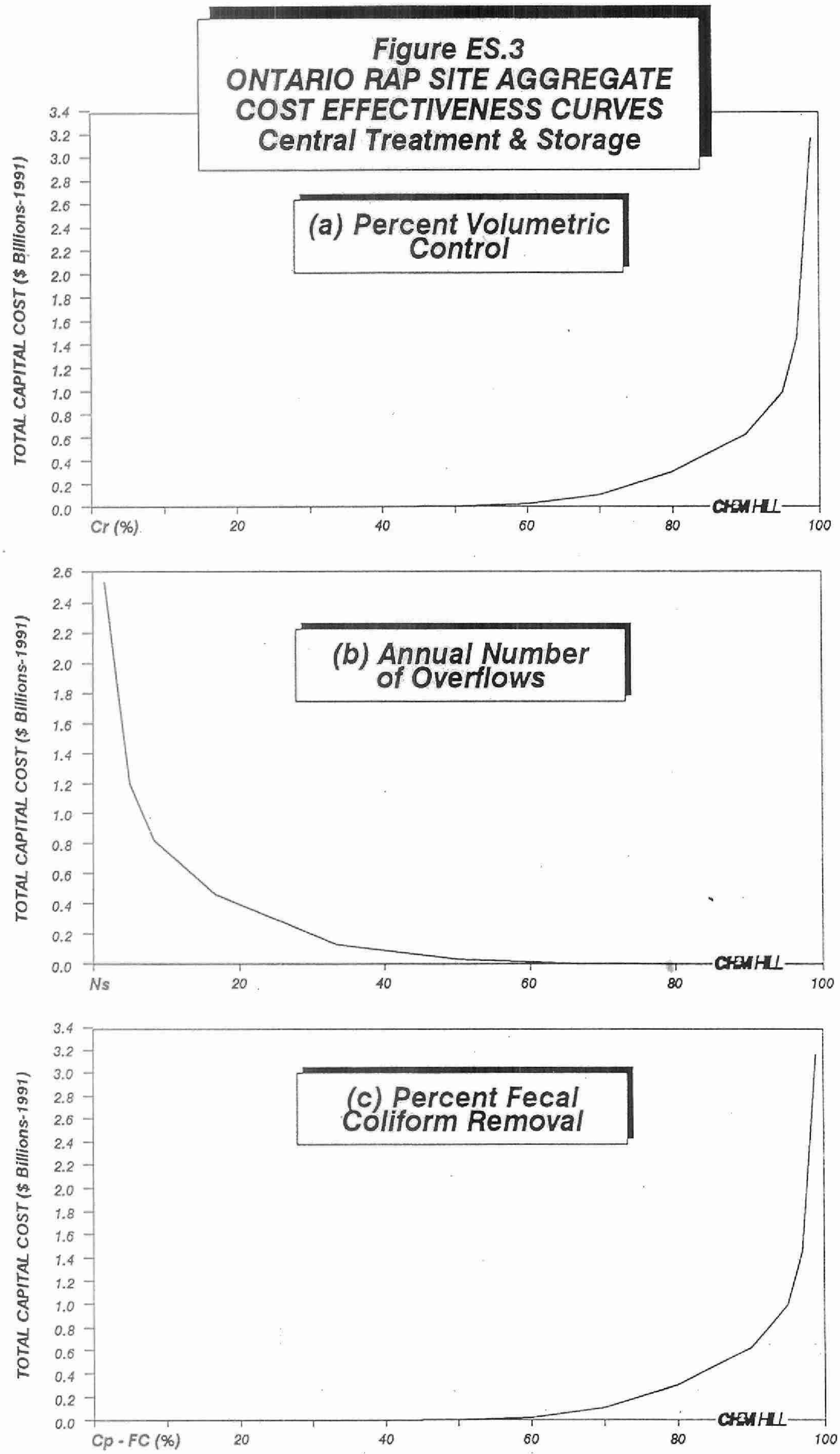

Figure ES.3
ONTARIO RAP SITE AGGREGATE
COST EFFECTIVENESS CURVES
Central Treatment & Storage
(a) Percent Volumetric Control
TOTAL CAPITAL COST ($ Billions-1991)
Cr (%)
CH2M HILL
(b) Annual Number of Overflows
TOTAL CAPITAL COST ($ Billions-1991)
Ns
CH2M HILL
(c) Percent Fecal Coliform Removal
TOTAL CAPITAL COST ($ Billions-1991)
Cp - FC (%)
CH2M HILL

TABLE ES.9
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$800	$0	$0	$1,700	$0	$0	$0	$0	$0	$100
50	$0	$2,700	$0	$7,800	$2,200	$0	$3,900	$0	$0	$0	$0	$700	$600
60	$1,100	$6,800	$5,600	$16,000	$5,700	$13,200	$6,600	$4,100	$200	$2,400	$0	$4,600	$2,900
70	$5,700	$12,000	$12,500	$26,500	$9,900	$34,200	$10,000	$9,900	$2,700	$5,400	$0	$9,400	$6,300
80	$11,800	$19,100	$21,900	$41,100	$15,900	$62,600	$15,000	$17,700	$6,000	$9,500	$6,800	$16,000	$11,000
90	$21,800	$31,900	$37,500	$68,000	$26,300	$109,100	$26,200	$30,500	$11,500	$16,200	$18,500	$27,200	$19,100
95	$33,100	$54,300	$57,500	$163,600	$43,900	$164,700	$76,300	$46,200	$17,700	$24,100	$30,600	$41,700	$32,500
97	$44,800	$147,100	$92,200	$319,100	$61,100	$230,900	$124,100	$66,600	$24,100	$33,000	$40,800	$70,500	$48,500
99	$102,800	$359,900	$156,500	$722,500	$108,500	$1,081,200	$245,200	$295,200	$102,800	$121,200	$64,900	$116,300	$138,900
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$400	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$7,400	$2,200	$0	$3,000	$0	$0	$0	$0	$0	$500
30	$0	$4,800	$6,900	$17,600	$6,400	$13,200	$6,300	$4,100	$1,200	$0	$0	$3,900	$1,900
20	$5,000	$11,600	$16,100	$31,600	$12,200	$40,900	$10,900	$11,700	$4,500	$4,000	$0	$10,300	$6,400
10	$14,500	$23,000	$31,100	$56,400	$22,000	$85,800	$19,700	$24,000	$9,900	$10,300	$11,300	$20,800	$13,900
5	$24,900	$38,100	$49,100	$98,300	$35,600	$136,500	$54,600	$38,200	$15,800	$17,200	$23,200	$33,300	$24,500
3	$34,300	$82,200	$70,600	$255,200	$58,900	$187,500	$97,000	$53,000	$21,600	$23,600	$32,900	$47,900	$37,900
1	$80,600	$263,200	$150,500	$624,300	$98,300	$848,800	$206,300	$235,900	$87,300	$77,900	$53,700	$103,100	$105,300
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$900	$0	$0	$1,700	$0	$0	$0	$0	$0	$100
50	$0	$2,700	$0	$7,800	$2,200	$0	$3,900	$0	$0	$0	$0	$700	$600
60	$1,100	$6,800	$5,600	$16,000	$5,700	$13,200	$6,600	$4,100	$200	$2,400	$0	$4,600	$2,900
70	$5,700	$12,000	$12,500	$26,500	$9,900	$34,200	$10,000	$9,900	$2,700	$5,400	$0	$9,400	$6,300
80	$11,800	$19,100	$21,900	$41,100	$15,900	$62,600	$15,000	$17,700	$6,000	$9,500	$6,800	$16,000	$11,000
90	$21,800	$31,900	$37,500	$68,100	$26,300	$109,100	$26,200	$30,500	$11,500	$16,200	$18,500	$27,200	$19,200
95	$33,100	$54,400	$57,600	$164,200	$44,000	$164,900	$76,500	$46,300	$17,700	$24,100	$30,700	$41,800	$32,600
97	$44,900	$147,700	$92,700	$321,300	$61,300	$231,400	$124,600	$66,800	$24,100	$33,000	$40,900	$70,700	$48,600
99	$103,300	$363,200	$157,400	$726,700	$108,900	$1,089,100	$246,300	$297,200	$103,700	$122,000	$65,200	$117,100	$139,800

TABLE ES.9 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,000	$0	$0	$0	$0	$0	$100
40	$1,000	$0	$0	$1,800	$2,200	$5,400	$3,400	$0	$0	$0	$0	$0	$500
50	$7,700	$3,400	$4,700	$9,100	$6,400	$31,400	$6,500	$2,700	$0	$1,100	$0	$4,100	$2,400
60	$19,600	$7,800	$12,300	$17,800	$12,200	$70,900	$10,700	$8,700	$900	$4,000	$0	$9,800	$5,900
65	$40,500												
70		$13,600	$23,100	$29,200	$22,000	$214,600	$17,800	$17,000	$3,600	$7,800	$3,900	$18,200	
75					$35,600								
77					$58,900								
79					$98,300								
80		$22,100	$45,100	$45,800			$96,200	$31,700	$7,600	$13,600	$14,300	$40,100	
82							$207,300					$77,800	
85			$147,300					$56,700					
87								$266,400					
90		$42,700		$85,000					$15,100	$49,000	$41,300		
95		$313,100		$408,900					$97,300				

STORAGE - SATELLITE TREATMENT - CENTRAL TREATMENT

The results of cost optimization for satellite treatment and storage are presented in Table ES.10 for Cr, Ns, Cp-FC and Table ES.11 for Cp-SS. Examination of results for percent volumetric control and annual number of overflows, where treatment removal efficiencies play no role, indicates that the lower cost of satellite treatment yields more balanced control strategies comprised of storage and treatment combinations. This is in clear contrast to the central treatment case described previously where due to cost, storage alone was preferred until the highest control levels.

The impact of pollutant removal efficiency upon the solution can be assessed by comparing the results in Table ES.10 for percent fecal coliform control and Table ES.11 for percent suspended solids control. In the case of fecal coliforms, the satellite treatment process efficiencies are high and balanced solutions of storage and treatment are preferred. In the case of suspended solids, process efficiencies are lower and in this instance storage is often the preferred solution.

Capital cost estimates reflecting the expansion paths for Cr, Ns, Cp-FC and Cp-SS are presented in Table ES.12. Costs have been, once again, aggregated only for Cr, Ns and Cp-FC. Treatment for the existing levels of control is assumed to be provided by the central WPCP. The combination of central and satellite treatment therefore yields different upper Cp-SS limits for each municipality which does not permit simple aggregation of costs. Once again, the shaded areas of the table indicate those plants not capable of achieving the noted control levels, and costs escalate sharply as these limits are approached. Figure ES.4 presents the cost effectiveness curves for Cr, Ns and Cp-FC respectively using satellite treatment and storage.

Table ES.13 presents these same costs on a per unit effective combined sewer area basis (i.e., $/hectare). Once again, unit area costs are generally uniform across the various municipalities. These unit costs are less variable than those for central treatment and storage, probably reflecting the fact that none of municipalities currently have satellite treatment and that its costs are the same on a flowrate basis for all municipalities.

TABLE ES.10
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
SATELLITE TREATMENT AND STORAGE

Municipality	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
	LEVEL OF VOLUMETRIC CONTROL					
	80%		90%		95%	
Thunder Bay	0	366,624	0	1,069,320	14,003	1,084,596
Midland	0	97,788	3,091	99,137	6,210	100,486
Sarnia	0	388,315	0	1,032,662	13,335	1,045,464
Windsor-East	0	276,994	0	688,896	8,492	697,507
Windsor-West	0	1,252,601	0	3,175,042	0	7,026,622
Fort Erie Total	0	89,544	3,231	90,636	6,507	92,820
Niagara Falls	0	680,011	0	1,634,774	0	3,551,170
Welland	0	211,594	0	575,626	7,394	582,451
Hamilton	0	1,200,730	0	3,616,483	0	8,433,696
Toronto Total	0	6,831,266	0	18,309,653	0	41,219,954
Belleville	0	79,757	0	347,597	5,704	352,358
Cornwall	0	279,240	0	736,764	9,845	743,208
Total	0	11,754,463	6,322	31,376,590	71,490	64,930,332
	ANNUAL NUMBER OF OVERFLOWS					
	10		3		1	
Thunder Bay	0	583,543	10,311	1,518,434	32,334	1,536,766
Midland	0	154,438	5,339	158,484	10,453	159,833
Sarnia	0	774,497	9,779	1,828,495	30,848	1,847,698
Windsor-East	0	523,848	14,771	536,765	28,704	542,506
Windsor-West	0	2,404,726	0	9,598,807	62,798	9,692,585
Fort Erie Total	0	168,168	5,551	172,536	10,875	174,720
Niagara Falls	0	1,153,958	14,310	2,617,013	45,506	2,644,488
Welland	0	393,610	12,893	402,710	25,122	407,261
Hamilton	0	2,815,997	0	12,178,829	85,766	12,307,478
Toronto Total	0	9,294,240	0	41,824,080	0	134,720,009
Belleville	0	179,750	9,920	185,702	19,344	189,274
Cornwall	0	485,448	7,250	1,164,216	22,823	1,174,956
Total	0	18,932,222	90,123	72,186,072	374,572	165,397,572
	LEVEL OF FECAL COLIFORM REMOVAL					
	80%		90%		95%	
Thunder Bay	0	366,624	0	1,072,375	0	2,480,822
Midland	0	97,788	3,119	99,137	6,266	100,486
Sarnia	0	388,315	0	1,034,796	0	2,329,891
Windsor-East	0	276,994	0	690,331	8,611	697,507
Windsor-West	0	1,252,601	0	3,181,740	0	7,040,018
Fort Erie Total	0	89,544	3,276	90,636	6,552	92,820
Niagara Falls	0	680,011	0	1,634,774	0	3,558,038
Welland	0	211,594	0	575,626	7,584	582,451
Hamilton	0	1,215,024	0	3,630,778	0	8,462,285
Toronto Total	0	6,831,266	0	18,309,653	0	41,312,897
Belleville	0	79,757	0	347,597	5,803	352,358
Cornwall	0	279,240	0	736,764	10,024	745,356
Total	0	11,768,758	6,395	31,404,206	44,841	67,754,930

TABLE ES.11
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
SATELLITE TREATMENT AND STORAGE
(% SUSPENDED SOLIDS REMOVAL)

Percent Suspended Solids Removal	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
Thunder Bay		
50	10,311	0
60	29,661	0
65	69,888	0
Midland		
70	3,428	0
80	5,957	0
90	13,994	0
Sarnia		
70	19,914	0
80	44,450	0
82	60,185	0
Windsor-East		
70	10,106	0
80	16,923	0
90	38,332	0
Windsor-West		
70	86,800	355,015
75	147,644	361,714
77	250,911	368,412
Fort Erie Total		
50	2,002	0
60	5,005	0
70	21,112	0
Niagara Falls		
60	27,761	0
70	51,230	0
75	89,008	0
Welland		
70	9,480	0
80	19,718	0
85	40,954	0
Hamilton		
90	153,069	414,538
92	198,335	414,538
94	333,536	428,832
Toronto Total		
70	220,738	1,626,492
80	437,604	1,672,963
90	1,624,556	1,719,434
Belleville		
70	1,488	0
80	6,547	0
90	23,362	0
Cornwall		
60	8,503	0
70	16,916	0
80	45,645	0

TABLE ES.12
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Winsdor East	Winsdor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$60,000	$0	$0	$460,000	$0	$0	$0	$0	$0	$530,000
50	$0	$160,000	$0	$440,000	$830,000	$0	$1,110,000	$0	$0	$0	$0	$110,000	$2,640,000
60	$260,000	$410,000	$650,000	$920,000	$2,160,000	$210,000	$1,950,000	$400,000	$0	$4,150,000	$0	$630,000	$11,750,000
70	$1,220,000	$760,000	$1,560,000	$1,600,000	$4,010,000	$570,000	$3,120,000	$1,020,000	$2,140,000	$10,080,000	$0	$1,360,000	$27,450,000
80	$2,730,000	$1,310,000	$2,980,000	$2,660,000	$6,920,000	$1,140,000	$4,970,000	$2,000,000	$5,510,000	$19,390,000	$750,000	$2,500,000	$52,870,000
90	$5,820,000	$3,700,000	$5,910,000	$4,850,000	$12,880,000	$3,600,000	$8,750,000	$4,010,000	$12,400,000	$38,470,000	$2,390,000	$4,830,000	$107,590,000
95	$13,730,000	$6,100,000	$13,530,000	$10,210,000	$22,240,000	$6,090,000	$14,680,000	$8,830,000	$23,230,000	$68,450,000	$6,310,000	$10,830,000	$204,240,000
97	$19,960,000	$8,060,000	$19,520,000	$14,420,000	$36,730,000	$8,110,000	$23,020,000	$12,630,000	$36,300,000	$104,610,000	$9,390,000	$15,560,000	$308,290,000
99	$27,550,000	$9,770,000	$26,700,000	$22,210,000	$59,770,000	$9,870,000	$37,880,000	$19,630,000	$69,760,000	$207,940,000	$15,070,000	$24,280,000	$530,430,000
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$140,000	$0	$0	$0	$0	$0	$140,000
40	$0	$0	$0	$390,000	$830,000	$0	$840,000	$0	$0	$0	$0	$0	$2,060,000
30	$0	$260,000	$780,000	$970,000	$2,430,000	$210,000	$1,820,000	$400,000	$1,090,000	$0	$0	$500,000	$8,470,000
20	$1,000,000	$700,000	$2,020,000	$1,900,000	$4,950,000	$680,000	$3,340,000	$1,210,000	$4,080,000	$6,730,000	$0	$1,420,000	$28,030,000
10	$3,340,000	$1,580,000	$4,540,000	$3,780,000	$10,100,000	$1,640,000	$6,480,000	$2,880,000	$10,200,000	$20,520,000	$1,270,000	$3,320,000	$69,640,000
5	$7,010,000	$3,980,000	$8,510,000	$9,120,000	$18,200,000	$4,120,000	$11,400,000	$7,680,000	$19,810,000	$42,180,000	$5,160,000	$6,300,000	$143,460,000
3	$13,320,000	$5,870,000	$14,620,000	$13,330,000	$27,960,000	$6,080,000	$19,660,000	$11,450,000	$31,410,000	$68,310,000	$8,230,000	$11,100,000	$231,330,000
1	$24,650,000	$9,400,000	$25,550,000	$21,150,000	$54,070,000	$9,720,000	$34,460,000	$18,500,000	$64,740,000	$142,980,000	$13,960,000	$19,700,000	$438,900,000
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$60,000	$0	$0	$460,000	$0	$0	$0	$0	$0	$530,000
50	$0	$160,000	$0	$440,000	$830,000	$0	$1,110,000	$0	$0	$0	$0	$110,000	$2,650,000
60	$270,000	$410,000	$650,000	$920,000	$2,160,000	$210,000	$1,950,000	$400,000	$200,000	$4,150,000	$0	$630,000	$11,950,000
70	$1,230,000	$760,000	$1,560,000	$1,600,000	$4,010,000	$570,000	$3,120,000	$1,020,000	$2,340,000	$10,080,000	$0	$1,360,000	$27,660,000
80	$2,730,000	$1,310,000	$2,990,000	$2,670,000	$6,920,000	$1,140,000	$4,970,000	$2,010,000	$5,710,000	$19,400,000	$750,000	$2,500,000	$53,090,000
90	$5,820,000	$3,720,000	$5,910,000	$4,850,000	$12,880,000	$3,630,000	$8,750,000	$4,010,000	$12,610,000	$38,490,000	$2,390,000	$4,830,000	$107,910,000
95	$10,690,000	$6,130,000	$10,510,000	$10,270,000	$22,270,000	$6,120,000	$14,700,000	$8,890,000	$23,460,000	$68,530,000	$6,350,000	$10,900,000	$198,820,000
97	$17,180,000	$8,090,000	$16,760,000	$14,490,000	$36,980,000	$8,140,000	$23,170,000	$12,690,000	$36,580,000	$104,820,000	$9,440,000	$15,640,000	$303,990,000
99	$28,630,000	$12,070,000	$27,780,000	$22,320,000	$63,000,000	$12,210,000	$38,100,000	$19,730,000	$70,410,000	$209,040,000	$15,150,000	$24,410,000	$542,870,000

TABLE ES.12 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Winsdor East	Winsdor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,630,000	$0	$0	$0	$0	$0	$1,630,000
40	$900,000	$0	$0	$520,000	$1,910,000	$330,000	$5,580,000	$0	$0	$0	$0	$0	$9,240,000
50	$6,520,000	$790,000	$2,590,000	$2,420,000	$10,920,000	$1,820,000	$10,530,000	$1,120,000	$0	$5,200,000	$0	$2,540,000	$44,450,000
60	$16,470,000	$1,830,000	$6,730,000	$4,730,000	$22,930,000	$4,090,000	$17,290,000	$3,590,000	$2,050,000	$39,870,000	$0	$6,010,000	$125,590,000
65	$34,210,000												
70		$3,180,000	$12,640,000	$7,710,000	$42,740,000	$12,710,000	$28,860,000	$6,990,000	$14,730,000	$84,740,000	$1,320,000	$11,150,000	
75					$67,550,000		$45,760,000						
77					$105,090,000								
80		$5,170,000	$24,670,000	$12,100,000				$13,010,000	$32,320,000	$152,660,000	$4,760,000	$24,760,000	
82			$33,110,000										
85								$23,710,000					
90		$10,140,000		$22,880,000					$65,580,000	$410,270,000	$13,690,000		
92									$85,210,000				
94									$131,630,000				

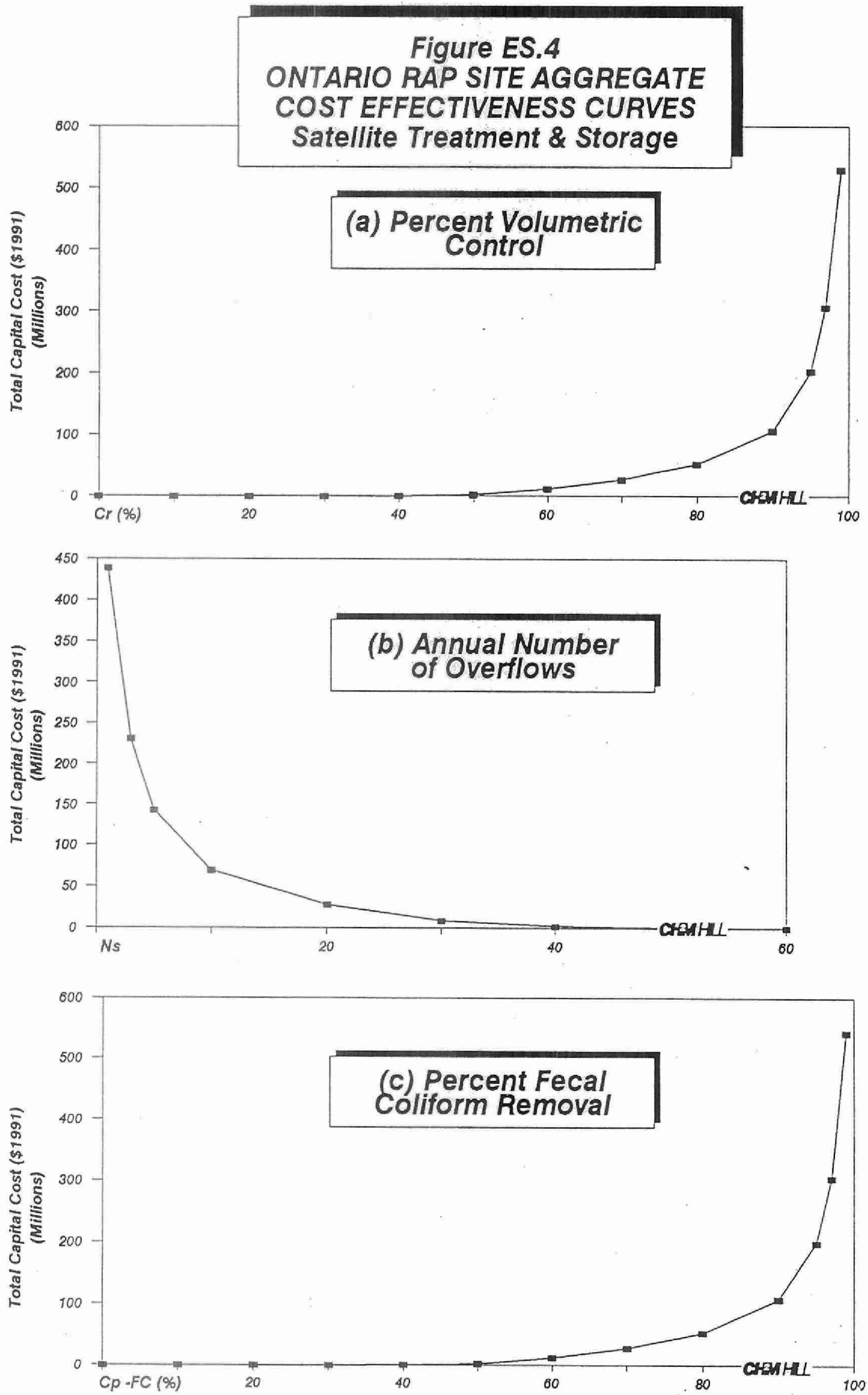

Figure ES.4
ONTARIO RAP SITE AGGREGATE
COST EFFECTIVENESS CURVES
Satellite Treatment & Storage
(a) Percent Volumetric Control
Total Capital Cost ($1991) (Millions)
600
500
400
300
200
100
0
Cr (%)
20
40
60
80
100
CH2M HILL
(b) Annual Number of Overflows
Total Capital Cost ($1991) (Millions)
450
400
350
300
250
200
150
100
50
0
Ns
20
40
60
CH2M HILL
(c) Percent Fecal Coliform Removal
Total Capital Cost ($1991) (Millions)
600
500
400
300
200
100
0
Cp -FC (%)
20
40
60
80
100
CH2M HILL

TABLE ES.13
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$100	$0	$0	$200	$0	$0	$0	$0	$0	$0
50	$0	$600	$0	$700	$300	$0	$400	$0	$0	$0	$0	$100	$100
60	$200	$1,500	$700	$1,500	$800	$500	$700	$400	$0	$200	$0	$700	$300
70	$1,000	$2,700	$1,800	$2,700	$1,400	$1,300	$1,100	$1,100	$400	$500	$0	$1,500	$700
80	$2,100	$4,700	$3,400	$4,400	$2,500	$2,500	$1,700	$2,100	$900	$1,000	$1,500	$2,800	$1,400
90	$4,600	$13,200	$6,600	$8,100	$4,600	$7,900	$3,100	$4,200	$2,100	$2,000	$4,800	$5,400	$2,900
95	$10,800	$21,700	$15,200	$17,100	$8,000	$13,400	$5,100	$9,300	$3,900	$3,500	$12,700	$12,100	$5,500
97	$15,700	$28,700	$22,000	$24,100	$13,200	$17,800	$8,000	$13,300	$6,100	$5,400	$18,900	$17,400	$8,400
99	$21,600	$34,800	$30,000	$37,100	$21,400	$21,700	$13,200	$20,700	$11,700	$10,700	$30,400	$27,100	$14,400
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$700	$300	$0	$300	$0	$0	$0	$0	$0	$100
30	$0	$900	$900	$1,600	$900	$500	$600	$400	$200	$0	$0	$600	$200
20	$800	$2,500	$2,300	$3,200	$1,800	$1,500	$1,200	$1,300	$700	$300	$0	$1,600	$800
10	$2,600	$5,600	$5,100	$6,300	$3,600	$3,600	$2,300	$3,000	$1,700	$1,100	$2,600	$3,700	$1,900
5	$5,500	$14,200	$9,600	$15,300	$6,500	$9,100	$4,000	$8,100	$3,300	$2,200	$10,400	$7,000	$3,900
3	$10,500	$20,900	$16,400	$22,300	$10,000	$13,400	$6,900	$12,100	$5,300	$3,500	$16,600	$12,400	$6,300
1	$19,400	$33,500	$28,700	$35,400	$19,400	$21,400	$12,000	$19,500	$10,900	$7,400	$28,100	$22,000	$11,900
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$100	$0	$0	$200	$0	$0	$0	$0	$0	$0
50	$0	$600	$0	$700	$300	$0	$400	$0	$0	$0	$0	$100	$100
60	$200	$1,500	$700	$1,500	$800	$500	$700	$400	$0	$200	$0	$700	$300
70	$1,000	$2,700	$1,800	$2,700	$1,400	$1,300	$1,100	$1,100	$400	$500	$0	$1,500	$800
80	$2,100	$4,700	$3,400	$4,500	$2,500	$2,500	$1,700	$2,100	$1,000	$1,000	$1,500	$2,800	$1,400
90	$4,600	$13,200	$6,600	$8,100	$4,600	$8,000	$3,100	$4,200	$2,100	$2,000	$4,800	$5,400	$2,900
95	$8,400	$21,800	$11,800	$17,200	$8,000	$13,500	$5,100	$9,400	$3,900	$3,500	$12,800	$12,200	$5,400
97	$13,500	$28,800	$18,900	$24,200	$13,200	$17,900	$8,100	$13,400	$6,100	$5,400	$19,000	$17,500	$8,300
99	$22,500	$43,000	$31,200	$37,300	$22,600	$26,800	$13,300	$20,800	$11,800	$10,800	$30,500	$27,300	$14,700

TABLE ES.13 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$600	$0	$0	$0	$0	$0	$0
40	$700	$0	$0	$900	$700	$700	$1,900	$0	$0	$0	$0	$0	$300
50	$5,100	$2,800	$2,900	$4,000	$3,900	$4,000	$3,700	$1,200	$0	$300	$0	$2,800	$1,200
60	$12,900	$6,500	$7,600	$7,900	$8,200	$9,000	$6,000	$3,800	$300	$2,100	$0	$6,700	$3,400
65	$26,900												
70		$11,300	$14,200	$12,900	$15,300	$27,900	$10,100	$7,400	$2,500	$4,400	$2,700	$12,500	
75					$24,200		$16,000						
77					$37,700								
80		$18,400	$27,800	$20,200				$13,700	$5,400	$7,900	$9,600	$27,700	
82			$37,200										
85								$25,000					
90		$36,100		$38,300					$11,000	$21,200	$27,600		
92									$14,300				
94									$22,100				

SUMMARY

The general conclusions which may be drawn from this study are:

1. CSO control costs escalate sharply (diminishing returns to scale) at higher levels of control such as 95 percent volumetric control or 1 overflow event annually.

2. Aggregate costs for higher levels of control are not significantly affected by existing levels of control in Ontario RAP municipalities, which range from 32 percent to 71 percent volumetric control and from 20 overflow events to 51 events annually.

3. The use of satellite treatment in combination with storage facilities is generally more cost-effective than storage facilities in combination with expansion of central treatment, especially with regard to volumetric control. In the case of pollutant control, the cost effectiveness of satellite treatment will be tempered by the relative pollutant removal efficiencies of satellite and central treatment. For example, in this study the control of suspended solids suffers under satellite treatment even though the volumetric control achieved may be equivalent.

4. The removal of suspended solids through any control strategy is limited by the treatment efficiency of the WPCP. This conclusion does not hold for faecal coliforms where removal efficiencies of 99.99 percent are achieved at both satellite and central treatment facilities, but will hold true for any other pollutant with limited removal at the central treatment facility (WPCP). This result is true of both satellite treatment/storage and central treatment/storage technology options.

5. Unit area costs are reasonably uniform across all municipalities for both storage with central treatment and storage with satellite treatment. Typical costs for storage with central treatment range from $10,000 to $30,000 per hectare of effective combined sewer area for 90 percent volumetric control. For storage with satellite treatment, corresponding costs are $2,000 to $6,000 per hectare. Once again, these cost advantages exist when considering volumetric control, but may not be as dramatic when considering pollutant control.

6. Consideration should be given to all the control criteria used in this study. For example, for the satellite treatment/storage option, examination of percent volumetric control, annual number of overflows and percent faecal coliform removal (high treatment efficiency) all indicated balanced control strategies comprised of storage and satellite treatment. Examination of percent suspended solids control, however, where treatment efficiencies of the satellite treatment facility are lower, indicated that storage alone (followed by central treatment) is often the preferred solution.

This study has shown that satellite treatment of CSO in combination with relatively small storage facilities is more cost effective than central treatment with relatively large storage facilities for volumetric control. This result will have different implications at each RAP site, and in order to interpret it, the following factors should be considered:

1. Control requirements.

   In general, pollutant removal efficiencies using satellite treatment are lower than for central treatment, notably for suspended solids. Satellite treatment may not be a permanent solution if contaminated sediments are the problem at a particular RAP site. On the other hand, if beach closures are the problem, then satellite treatment is clearly the favoured option, since it has an equivalent performance at a significantly lower cost.

2. The need for more detailed analysis.

   This study could not incorporate site specific factors in the analysis. More detailed modelling of each RAP site, such as that provided by a Pollution Control Planning (PCP) Study, should be considered if not already complete. Other means of gathering information, such as a field demonstration of satellite treatment, should also be considered.

3. Receiving water impairment studies.

   Before either of the preceding factors may be considered, it may be necessary to develop more detailed information on the nature of receiving water impairment at a particular RAP site. For example, while satellite treatment can provide excellent control of faecal coliforms discharged to the receiving water, the source of water quality impairment may actually be suspended solids, in which case, satellite treatment may be less desirable. Such information should be available before any CSO control strategy is embarked upon.

4. The accuracy and precision of the cost estimates.

   The control cost estimates for each site should be considered as reasonable planning level estimates of the magnitude of control costs, that indicate the relationship between expenditures and the effectiveness of the control for different control criteria.

GLOSSARY

Storm sewer: A sewer designed to carry storm sewage, connected to road surfaces through catch basins. Private property connections often include roof drainage downspouts and foundation drains.

Sanitary sewer: A sewer designed to carry sanitary sewage including industrial and commercial wastewater.

Combined sewer: A sewer designed to carry sanitary sewage in dry weather, and a mixture of sanitary sewage and storm sewage during runoff events.

Interceptor sewer: A sanitary sewer used in conjunction with a combined sewer system, designed to convey sanitary sewage to the Water Pollution Control Plant in dry weather. During wet weather, this sewer is usually designed to convey up to 3 times the dry weather flow.

Regulator: The point where the interceptor meets the combined sewer. The regulator controls the amount of flow intercepted and conveyed to the Water Pollution Control Plant, while the excess overflows.

Combined sewer overflow: The flow in the combined sewer in excess of the interception and treatment capacity, which during wet weather overflows to surface water bodies.

Section 1
INTRODUCTION

The International Joint Commission examining water quality problems in the Great Lakes has identified 17 Areas of Concern in Ontario. Remedial Action Plans (RAPS) are currently being developed for these areas to address water quality concerns such as point and non-point source discharges, contaminated sediments and impaired aquatic habitats. Nine of these RAP sites encompassing eleven municipalities are serviced at least in part by combined sewers and have experienced water quality impairment due to urban wet weather sources such as combined sewer overflow (CSO) and storm water. The eleven municipalities are:

- Thunder Bay
- Midland
- Sarnia
- Windsor
- Fort Erie
- Niagara Falls
- Welland
- Hamilton
- Metropolitan Toronto
- Belleville
- Cornwall

These were identified in earlier RAP studies (Ref. 2).

This study was undertaken to examine the cost implications of achieving progressively more stringent control levels through a number of different technologies for the affected Ontario RAP sites.

Specifically, the objectives of this study were:

1. To develop a simplified analysis methodology through the use of case studies from municipalities which had already completed detailed Pollution Control Plans (PCPs) addressing CSO problems.

2. To apply the methodology to Ontario RAP sites and develop preliminary performance and cost estimates for planning purposes.

This report is a summary document which provides information on both the technical background and methodology of the study and on study results for affected Ontario RAP sites. A complementary report (Ref. 1) summarizing the results of case studies for two municipalities provides more technical detail regarding the study methodology

and is referenced throughout the text as appropriate. This report is structured to provide detailed technical information, such as mathematical equations, in the form of qualitative descriptions of calculations. In this manner, the utility, technical nature and limitations of the study results will be communicated without compromising the clarity and flow of the text.

This report contains an additional three sections. Section 2 documents the study approach, describes CSO phenomena in general terms (Section 2.1) and describes the technical methodology developed specifically for this study (Section 2.2). This approach has been developed through the use of case studies from other municipalities which have already developed detailed PCPs, as described in Section 2.2.7.

The cost and performance of CSO control technologies at Ontario RAP sites are outlined in Section 3. The results of this study require careful interpretation, as discussed in Section 4, especially since they have been developed using a new methodology. Section 4 summarizes study results, highlights the advantages and limitations of this methodology and includes recommendations for further refinement in future applications.

Section 2
STUDY APPROACH

2.1 COMBINED SEWER OVERFLOWS AND THEIR EFFECTS

Although no longer used for new servicing, the older sections of many Ontario municipalities are still partly serviced by combined sewers. Combined sewers receive both storm and sanitary wastewater flows but are configured in such a way that flows in excess of the downstream pipe flow capacity or the treatment capacity at the Water Pollution Control Plant (WPCP) are discharged directly to receiving waters without treatment. Consequently, during periods of wet weather, overflows of combined storm and sanitary wastewater may occur. Flow regulators are provided within all combined sewer systems to provide relief by allowing excess flows to leave the system and therefore minimizing basement flooding and impairment of WPCP treatment capabilities. Such combined sewer overflows (CSOs) are cause for concern for two reasons. Firstly, the quality of receiving waterbodies may be adversely affected. Secondly, they are a concern with respect to the operation of systems such as the sewer collection system itself as well as the downstream WPCP.

The receiving water quality impacts of CSOs vary depending upon the quality and quantity of the wastewater and the assimilative capacity of the receiving waterbody. Potential water quality concerns resulting from CSOs include:

- Bacteria from fecal material.
- Nutrient enrichment, which can lead to unbalanced growth of organisms, such as algae, in the receiving waterbody.
- Solids deposition on benthos, the organisms living at the floor of the receiving waterbody.
- Toxicity from ammonia, metals and organic compounds present in the wastewater.
- Oxygen depletion potential ("oxygen demand") of the wastewater, which can lead to oxygen deprivation of the organisms in the receiving waterbody.
- Aesthetic impacts from floatable matter.

2.2 CSO SYSTEM ANALYSIS

2.2.1 Overview

The central objectives of this study were to develop an analysis methodology to examine the cost implications of increasing CSO control levels and to apply that methodology to analyze the Ontario RAP sites. Figure 2.1 describes the analysis methodology and its development.

The overall purpose of the methodology is to analyze the performance of CSO control systems according to various control criteria using a range of control technologies. This effort involves the development of a mathematical model to describe the combined sewer system and the catchment it serves. The goal in developing this model is to account for the features of the system which affect CSO control, while at the same time ensuring that the model is mathematically tractable. Thus a system description must be developed based on available information from which the performance analysis may proceed. As indicated in Figure 2.1, development of this system description and the performance analysis model is an iterative process and results in a model best suited to the analysis objectives.

Other information necessary to the performance analysis includes:

- Criteria by which to measure CSO control.
- CSO control technologies for analysis.
- Precipitation data.

The final step in the analysis is cost optimization. The performance analysis will provide information on which technologies or combination of technologies will meet given control criteria. Information on the costs of these technologies can then be used to determine the least cost means to reach a given control level. As with the performance analysis, the cost optimization is mathematically derived. In addition it depends upon equations describing control technology cost in terms of volumetric or flow capacity. As indicated in Figure 2.1, the cost optimization may be repeated for any combination of control technologies and control criteria in order to gain an understanding of the cost implications of these factors. Each of these elements in the methodology are discussed in further detail in the following sections.

2.2.2 CSO System Description

A simple schematic of a sewer catchment area is depicted in Figure 2.2 in order to describe the components of a generalized combined sewer system. This is the system

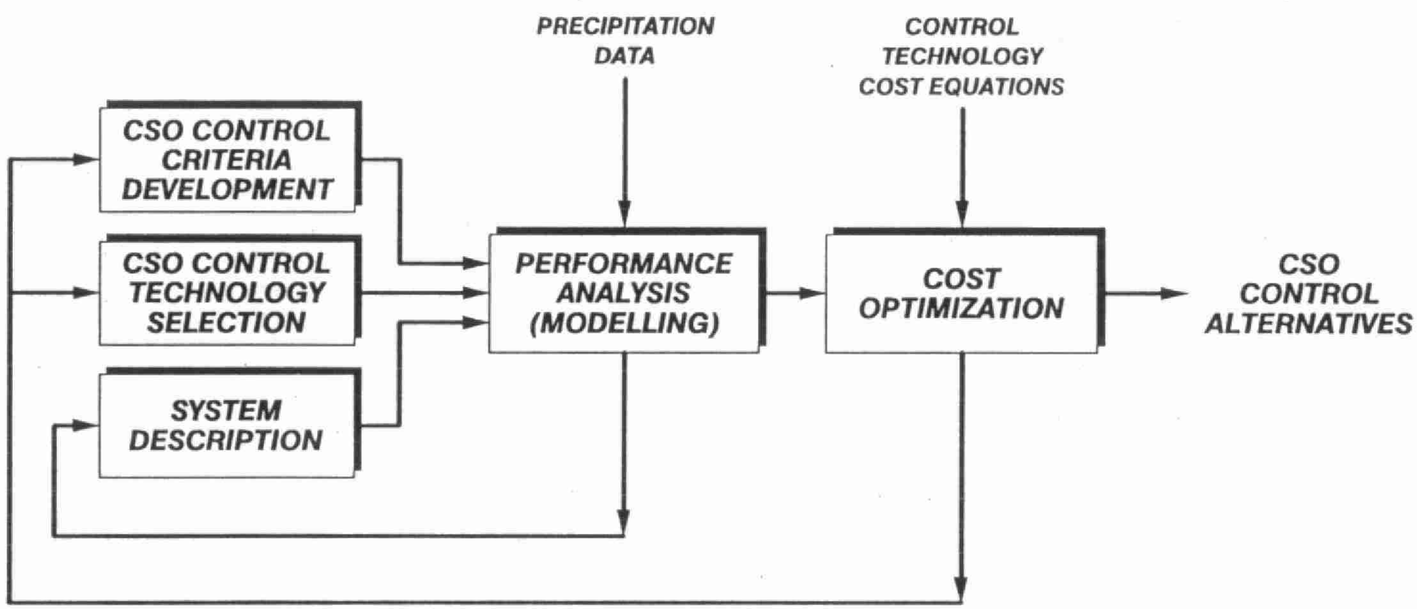

Figure 2.1
ANALYSIS METHODOLOGY DESCRIPTION AND DEVELOPMENT

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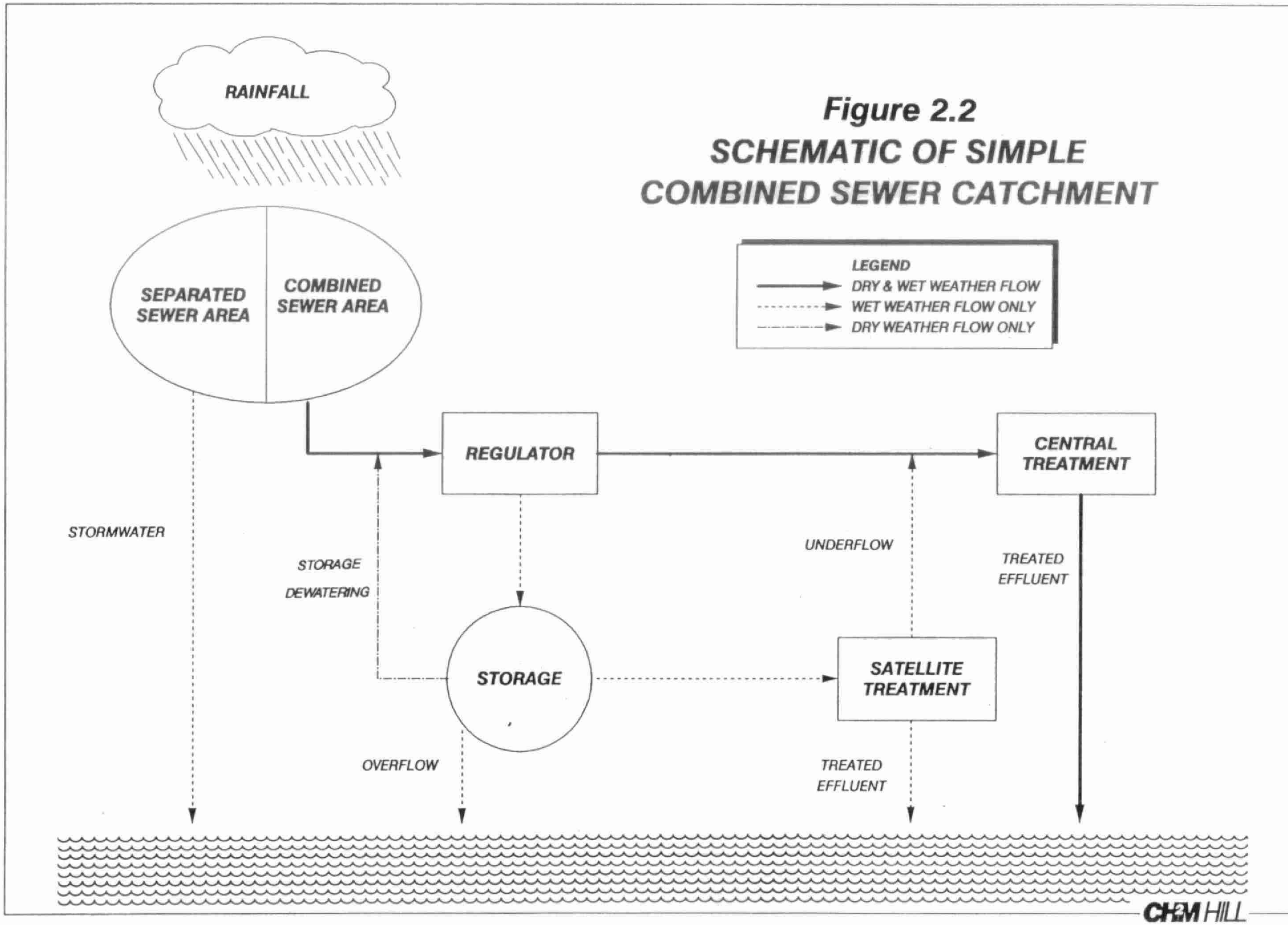

Figure 2.2
SCHEMATIC OF SIMPLE COMBINED SEWER CATCHMENT

used to develop the performance analysis and to examine the effects and costs of different control technologies and criteria for the Ontario RAP sites.

That fraction of rain which does not permeate the surface during a rainfall event is known as runoff and is collected by both separated and combined sewer systems. Runoff from separated areas is discharged directly as storm water. Runoff from combined sewer areas mixes with sanitary flows and reaches a flow regulator at some point upstream of the WPCP, referred to as the central treatment facility. The purpose of the flow regulator is to regulate flow to the central treatment facility in order that it may function adequately. Uncontrolled peak flows will not be fully treated and may impair the treatment capabilities of the plant, which may require as long as days or weeks to recover. When flow at the regulator exceeds that which the downstream sewer or the plant can handle, a combined sewer overflow (CSO) occurs. In most instances, this overflow is discharged directly and can result in the damage to the receiving waterbody noted previously.

Recent efforts to deal with this problem have included the installation of storage facilities or storage and satellite treatment facilities. The latter is described in more detail in the following section. During a wet weather event, CSO from the regulator flows to the storage tank and then to the satellite treatment facility. The satellite treatment facility also has a limiting capacity, which when reached, results in accumulation of wastewater in the storage facility and possibly eventual overflow to the receiving waterbody. Treated effluent from the satellite treatment facility is also discharged directly to the receiving waterbody. A small fraction of the discharge flow carries the contaminants removed from the treated effluent to central treatment. This stream is known as underflow. The central treatment facility also discharges a treated effluent to the receiving waterbody. Finally, at the end of a rain event, wastewater accumulated in the storage facility is directed to central treatment provided that adequate treatment capacity is available. This measure, known as storage dewatering, is favoured over using satellite treatment largely because pollutant removal efficiencies are generally higher at the central treatment facility.

In summary, there are four sources of discharges to the receiving waterbody:

- Storm water from separated sewer areas.
- Treated effluent from the satellite treatment facility.
- Overflow from the storage facility.
- Treated effluent from the central treatment facility.

In an intense rainfall event, all four sources will be discharging. In a less severe event, the satellite treatment facility will be capable of handling all of the regulator overflow and the storage facility will not overflow. In smaller events, all combined flows will flow through the regulator to central treatment and only discharges from separated areas and the central treatment facility will occur. During periods of no rainfall, the only discharges are those of treated sanitary dry weather flows from the central treatment facility.

The major simplification made in the system description for this analysis of Ontario RAP sites was that entire municipalities were considered as single catchment areas for the purposes of performance analysis, with characteristics of the catchment area and drainage system averaged over the entire area. For example, the value of the volumetric runoff coefficient was selected to reflect the entire urban drainage area that was being modelled, including all catchments and all separated and combined areas. Thus, the mathematical model accounts for pollutant loading from separated sewers by modelling them as equivalent combined sewers. Flow regulator capacity was assumed equal to the WPCP wet weather treatment capacity since all catchments were considered as one catchment feeding the WPCP.

2.2.3 CSO Control Technologies

Several technologies exist for the control of CSO water quality impacts, most based on reducing the volume or number of overflows, or on improving the quality of the wastewater directly discharged. The most obvious control technology is a sewer separation program whereby road drainage, roof drains and/or building foundation drains are disconnected. The storm water is then discharged directly, does not come into contact with sanitary wastewater and may be handled as a separate issue as far as quantity and quality impacts on the receiving water are concerned.

Storage of excess flows with subsequent central treatment of CSO at the WPCP is a second control alternative. However, this alternative depends on the availability of adequate treatment capacity at the WPCP. Typically in Ontario, WPCPs have excess capacity in two forms. Firstly, excess capacity exists to accommodate future population growth in the area serviced by the WPCP. Secondly, plants are generally designed with using a peaking factor. This means that under peak flow conditions, such as during wet weather events, the plant can treat some multiple (often 2.5 times) of average design treatment capacity. However, it should be noted that under this scheme, the plant can operate at reduced pollutant removal efficiency. For areas with substantial CSO problems, expansion of the WPCP treatment capacity to handle these flows may be considered. However, if CSO volumes can be retained in separate, decentralized storage facilities for treatment at the WPCP once flows have subsided following a wet weather event, then expansion of the WPCP treatment capacity to handle wet weather flows can be wholly or partly avoided.

A relatively new control technology beginning to receive widespread consideration is the use of so-called satellite treatment. This technology involves the use of physical/chemical treatment technologies to pre-treat CSO prior to direct discharge. These technologies typically include operations such as various combinations of operations such as:

- Coarse screens to remove large solids and floatable materials.
- Vortex separators to remove heavier particulates and floatables.

- High rate sedimentation basins operated with coagulant addition to enhance settling.

- Disinfection facilities using ultraviolet (UV) light or chlorination to kill off bacteria. Chlorination facilities should normally be followed by dechlorination operations to avoid toxic effects in the receiving water-body.

This approach reduces the amount of wastewater requiring central treatment, thereby once again avoiding WPCP expansion costs. This technology can be cost-effective when used in conjunction with storage facilities. Treatment efficiencies of these physical-chemical treatment technologies, however, may be somewhat lower than that of secondary treatment at the WPCP.

It should be noted that, in many cases, a specific combination of these technologies affords the most cost-effective solution to CSO problems. However, detailed study of individual sewer catchments is required to make this determination and is usually part of a Pollution Control Planning study.

2.2.4 CSO Control Criteria

A number of criteria have been proposed against which CSO control may be measured. Each has its advantages and disadvantages, but two of the most popular criteria currently in use are:

- Number of overflow, or "spill", events per year (symbol: Ns).

- Percent volumetric control, or the yearly volume of flow which is retained and/or subsequently treated and is not lost as overflow, as a percentage of total yearly wet weather volume (symbol: Cr).

These two control criteria consider only the volume of wastewater and not its degree of contamination nor the treatment removal efficiency of satellite or central treatment facilities. These factors are important when:

- New effluents are created through the use of sewer separation as a control technology. The volume and frequency of CSO may be substantially reduced, but impacts on the receiving waterbody due to direct discharge of untreated storm water may still be substantial.

- Treatment removal efficiencies are low. For example, a WPCP may be expanded to handle CSO, reducing its volume and frequency to zero. However, if the WPCP is only capable of reducing pollutant levels by 10 to 20 percent, impacts on the receiving waterbody may still be substantial.

In order to examine these effects, a third criteria has been proposed:

- Percent pollutant control, or the yearly mass of a specified pollutant which is retained and/or subsequently treated and is not directly discharged, as a percentage of total yearly mass in wet weather flows (symbol: Cp).

The two pollutants most commonly examined in a CSO context are suspended solids (symbol: SS) which are measured as mass per unit volume (e.g., mg/L) and fecal coliforms (symbol: FC) which are measured as number of fecal coliform bacteria organisms per unit volume (e.g. number of organisms/100 mL). Other pollutants which may be considered include ammonia, heavy metals, organic compounds and other potentially toxic contaminants. Quantitative data on levels in combined, untreated wastewater and treatment removal efficiencies for these contaminants are still relatively scarce.

Consideration of all of these control criteria will give the most balanced approach to managing CSO problems.

2.2.5 Performance Analysis

The two major types of models which have been developed for CSO performance analysis are referred to as deterministic and probabilistic.

An example of a deterministic model is STORM, or the Storage, Treatment, Overflow and Runoff Model (Ref. 8). STORM makes use of the following information:

- System description including runoff coefficient, regulator capacity and storage volume.

- Precipitation data in the form of hourly records for a one-year or multi-year period.

The model essentially uses this information to create an hourly CSO flow data record which corresponds in time to the input rainfall data. The model can be used to estimate levels of control for selected control criteria and control technologies, but does not incorporate cost optimization calculations.

An example of a probabilistic model is SUDS, or the Statistical Urban Drainage Simulator(Ref. 8). This model uses hourly rainfall data records for a one-year or multi year period and a user-selected interevent time to calculate the following statistical averages:

- Storm volume
- Storm duration
- Storm intensity

- Number of rain events.

By assuming that the distribution of rainfall parameters about these averages is exponential in nature, and by providing a system description, the expected volume of runoff, the expected frequency and volume of overflows and the expected percent pollutant control can be derived mathematically.

As with STORM, SUDS does not perform cost optimization.

2.2.6 Cost Optimization

The STORM and SUDS models provide information on the performance of control technologies for various combinations of control technologies such as storage, satellite treatment and central treatment. However, neither STORM nor SUDS by themselves can be used directly to develop cost estimates for control technologies or establish which combination of storage and treatment is gives a least cost solution for a given target level of control.

An extended version of the SUDS model, known as EXSUDS (Ref. 8), is capable of accepting information on costs of control technologies and calculating the optimal, cost-effective combination of technologies for a given catchment. This was the model used in this study. Before understanding how EXSUDS performs these calculations, however, a more fundamental understanding of the cost optimization process is required. This understanding is best communicated through the use of graphs presented in Figures 2.3 and 2.4.

Figure 2.3 is a plot of amount of storage against amount of treatment. The curves on the plot represent lines of constant performance, such as 80 percent volumetric control, and are known as performance isoquants. Thus each point on the 80 percent volumetric control performance isoquant represents a unique combination of storage and treatment capacity required to achieve 80 percent volumetric control. It should also be noted that each point on these lines is generated by running STORM or SUDS for that combination of storage and treatment. Since some level of storage and treatment may already be present in a given catchment, and since it is not normally recommended to reduce available storage or treatment, the range of feasible control targets for that catchment lie in the unshaded area of Figure 2.3.

The next step is to incorporate cost information into a graph such as Figure 2.4. Cost equations giving the cost of control technologies as a function of treatment or storage capacity have been developed as part of this work. The components included in these costs and assumptions made are detailed in a previous report (Ref. 1).

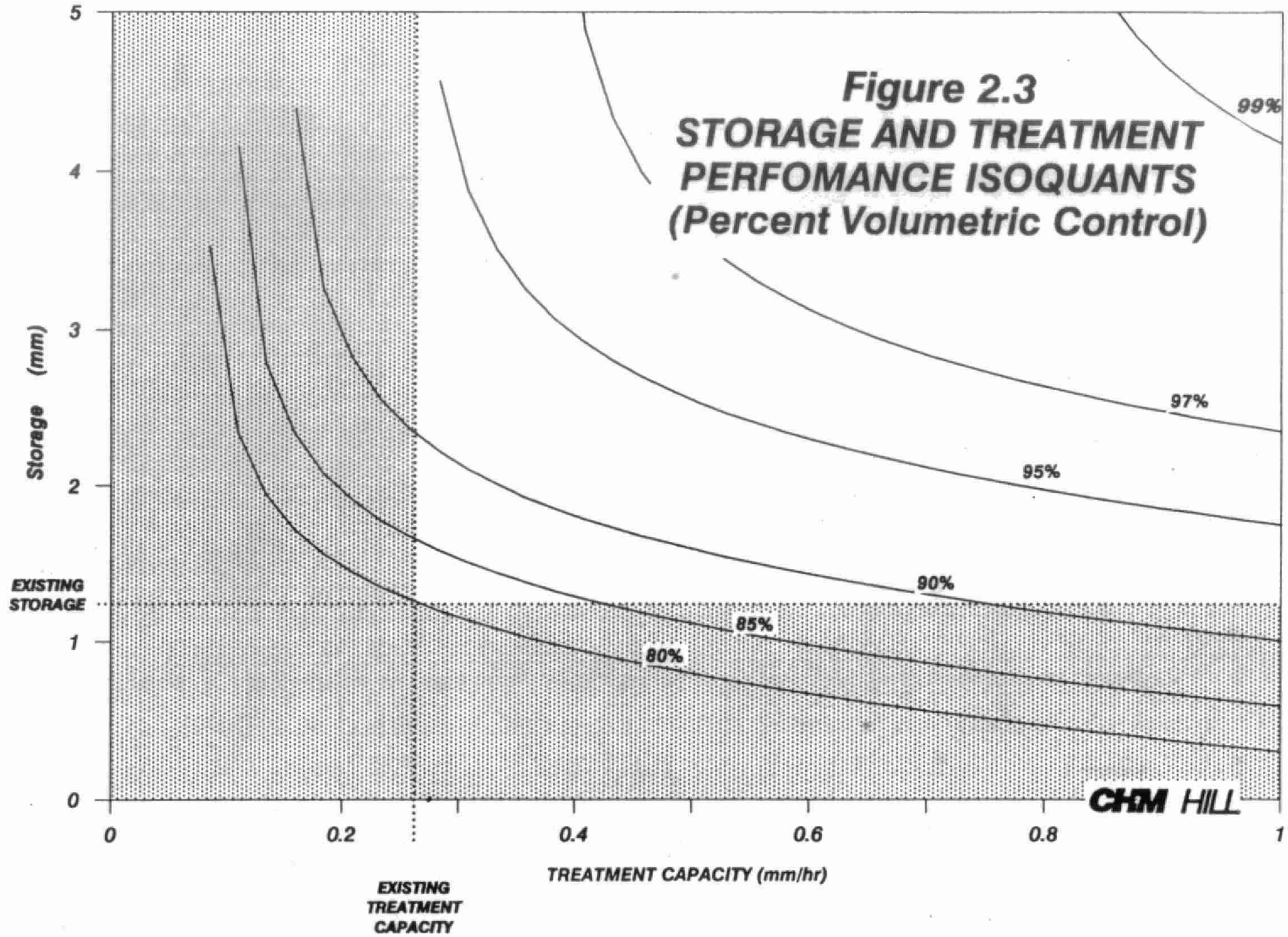

Figure 2.3
STORAGE AND TREATMENT PERFOMANCE ISOQUANTS
(Percent Volumetric Control)

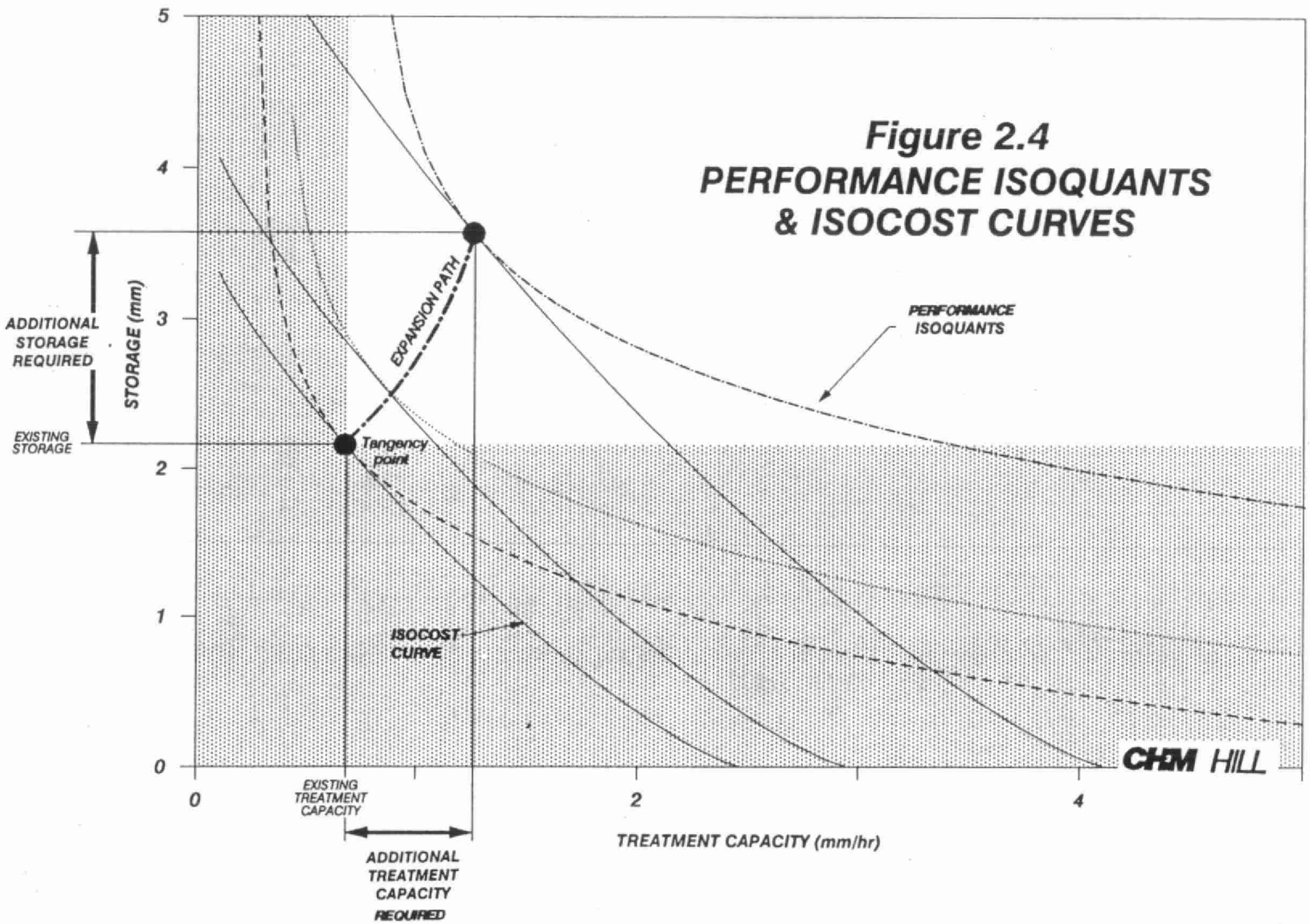

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Table 2.1 summarizes the cost equations used in the analysis of Ontario RAP sites. These equations account for economies of scale which are realized when larger facilities are constructed. In the case of satellite treatment facilities, more than one facility may be constructed in the larger municipalities and some of these economies of scale may be lost. However, it is important to point out that only the largest municipalities such as Metro Toronto may consider more than one facility and that in general these facilities will be centralized. None of the cost equations in Table 2.1 account for any conveyance improvements which may be required for any of the technologies. In this table, V is the storage volume required in cubic meters and Q is the treatment capacity in cubic meters per second. The equations for annual equivalent costs give the annualized capital costs plus annual operation and maintenance costs. Two sets of equations are given for expansion of central treatment capacity. Existing plants provide either primary treatment, consisting essentially of solids removal, or they provide more advanced secondary biological treatment. Expansion costs are higher for secondary WPCPs. Upgrading a primary plant to secondary treatment capability was not considered in this study.

Table 2.1
Ontario RAP Municipalities Pollution Control Cost Equations

Technology	Total Capital Costs (1991$)	Annual Equivalent Costs (1991$)
Storage Dewatering at Central Treatment	$4,100 * $V^{0.79}$ (m^3)	$320 * $V^{0.79}$ (m^3)
Satellite Treatment Vortex Separator - Chlorination, Dechlorination	$790,000 * $Q^{0.65}$ (m^3/s)	$180,000 * $Q^{0.48}$ (m^3/s)
Central Treatment Primary	$23,630,000 * $Q^{0.67}$ (m^3/s)	$4,100,000 * $Q^{0.72}$ (m^3/s)
Central Treatment Secondary	$95,530,000 * $Q^{0.73}$ (m^3/s)	$10,770,000 * $Q^{0.74}$ (m^3/s)

Notes:

1. Higher costs would be incurred for satellite treatment if coarse screens and sedimentation basins were included.

These cost equations are used to plot the isocost curves in Figure 2.4. The intersection of the lowest cost isocost curve with the desired performance isoquant at the tangency point gives the levels of storage and treatment required. The expansion path is the locus of the least cost tangency points and represents the incremental amounts of storage and treatment which must be provided to achieve ever greater levels of control in the most cost-effective manner possible.

It is possible to describe this cost optimization process through mathematical expressions without developing graphs such as Figures 2.3 and 2.4. In this way, equations for the performance isoquants and isocost curves are developed and the point at which their slopes are equal represents the tangency point. This, in effect, is the calculation

performed by the EXSUDS model. The results obtained from the model include the additional amounts of storage and/or treatment required, and their costs.

In summary, the EXSUDS model provides information on the performance and costs of optimal amounts of storage and treatment required for a given catchment, given precipitation data, a system description, CSO control technology cost equations and the desired level of control.

Further refinements of EXSUDS were necessary in this study to analyze satellite treatment as an alternative CSO control technology to central treatment. These refinements involved changes to the mathematical expressions used to calculate Cp, the percent pollutant control, to ensure that all possible sources of pollutant loadings were accounted for, including effluent from satellite treatment facilities.

2.2.7 Kingston and St. Catharines Case Studies

The details of this analysis methodology were developed through case study analysis and are discussed in a separate report (Ref. 1). The cities of St. Catharines and Kingston have both recently completed Pollution Control Plans which involved detailed modelling of CSO phenomena. Results from the modified EXSUDS approach developed as a part of this study for these two cities were compared to detailed results from PCP development.

In the Kingston case study, single catchments were grouped into four so-called megacatchments for the purposes of modelling. For St. Catharines, the model was further developed to allow grouping together all catchments feeding each of two WPCPs. This latter approach is most similar to the method used for the Ontario RAP sites where the availability of data describing catchments, and the scope of the study, limited the degree of detail in system descriptions.

The results of detailed STORM modelling from PCPs for these cities were compared to EXSUDS modelling as documented in Tables 2.2 and 2.3. In the case of both cities, correspondence between these two sets of results was deemed adequate for the purposes of this study. These results provided some measure of validation for the modified EXSUDS approach and allowed comparison to costs developed as part of the PCPs conducted in Kingston and St. Catharines.

The costs estimated to achieve one overflow event per year by the modified EXSUDS model differ from those estimated by the detailed analysis of the PCPs by approximately plus-or-minus 30 percent. In general, where less accurate information on the catchment area may be available, it is believed that the uncertainty in these estimates is order-of-magnitude (within a factor of ten).

Table 2.2 Comparison of STORM and EXSUDS Results for Kingston			
Catchment Number	STORM	EXSUDS	Difference
% Volumetric Control			
1	46%	58%	+12%
14	81%	82%	+1%
36	51%	50%	-1%
37	94%	88%	-6%
Annual Frequency of Overflow			
1	35	27	-8
14	12	12	0
36	32	33	+1
37	4	8	+4

Table 2.3 Comparison of STORM and EXSUDS Results for St. Catharines			
Catchment	STORM	EXSUDS	Difference
% Volumetric Control			
Port Weller	97%	92%	-5%
Port Dalhousie	68%	55%	-13%
Annual Frequency of Overflow			
Port Weller	3	5	+2
Port Dalhousie	21	29	+8

The results of case study analysis were important in formulating control scenarios considered for analysis, as well as in developing an understanding of the accuracy of cost estimates for the Ontario RAP sites.

The modified EXSUDS model developed and used in this study is a powerful tool which may be used to analyze CSO problems at a preliminary level to assist planning decisions without resorting to detailed PCP analysis. For these reasons, it is well suited for this preliminary analysis of Ontario RAP sites.

Section 3
COST AND PERFORMANCE OF CSO CONTROL TECHNOLOGIES AT ONTARIO RAP SITES

3.1 BACKGROUND

The methodology described in Section 2.3 has been applied to each of the RAP areas affected by CSO, including Thunder Bay, Midland, Sarnia, Windsor, Fort Erie, Niagara Falls, Welland, Hamilton, Metropolitan Toronto, Belleville and Cornwall. Summary information on non-point source pollution problems at these sites has been provided in a previous study (Ref. 2). This section presents results regarding the cost and performance of CSO control technologies in these municipalities.

Data describing the catchment areas and central treatment facilities connected with each Ontario RAP site municipality are provided in Table 3.1, with references as noted. Information on WPCPs for each of the municipalities was gathered since the flow regulator capacity is taken as the WPCP wet weather treatment capacity (net of average dry weather flow). Average dry weather flows are in fact, overestimated by the data provided by the reference noted in Table 3.1, since these averages included wet weather periods. However, these were the best estimates available. The plant type, primary or secondary, has a bearing on expansion costs and pollutant removal efficiencies as noted previously. These data were the starting point for applying EXSUDS and developing cost estimates for different control scenarios.

Runoff coefficients were developed using the data on land use and sewer types. Separated sanitary sewers collect wet weather flows through inflow and infiltration and therefore contribute wet weather flows to the overall sewer system. The amount of this contribution is small, as indicated by the estimated value of 0.05 for the runoff coefficient for separated areas in Table 3.2. Runoff coefficients for combined areas were estimated based on a weighted average of typical values for the various land uses reported in Table 3.1. The overall runoff coefficient is a weighted average of the values for separated and combined sewer areas.

The modified EXSUDS model considers all catchments as a single combined sewer area. Since the RAP municipalities have areas of separated sewers, a further modification was required in order to use the combined area runoff coefficients for each municipality. This was achieved through the use of effective combined sewer area which is given by the ratio of the overall runoff coefficient to the combined runoff coefficient, multiplied by the total area.

Also indicated in Table 3.2 are the net plant capacity for wet weather flow (WWF) and net WWF treatment rate. The net plant capacity is the difference between the peak plant capacity (using the 2.5 peaking factor noted earlier) and the average dry weather

TABLE 3.1
ONTARIO RAP MUNICIPALITIES CHARACTERISTICS

Municipality	CATCHMENT PARAMETERS							WPCP DATA			
	Area by Land Use				Area by Sewer Type			Average Annual DWF (m3/d)	WPCP Design Capacity (m3/d)	Plant Type	Plant Name
	Res. (ha)	Comm. (ha)	Indust. (ha)	Open (ha)	Total (ha)	Comb. (ha)	Separated (ha)				
Thunder Bay	2,030	177	711	772	3,690	830	2,860	78,130	109,100	P	THUNDER BAY WPCP
Midland	316	31	111	104	562	231	331	11,350	13,680	S	MIDLAND WPCP
Sarnia	1,600	160	1,090	350	3,200	540	2,660	35,640	65,910	P	SARNIA WPCP
Windsor-East	1,950	149	496	110	2,705	260	2,445	37,720	36,360	S	LITTLE RIVER WPCP
Windsor-West	5,110	391	1,300	294	7,095	2,100	4,995	117,510	163,650	P	WESTERLY WPCP
Fort Erie (Anger Ave.)								10,690	16,360	S	ANGER AVE. WPCP
Fort Erie (Crystal B.)								4,250	3,880	S	CRYSTAL BEACH WPCP
Fort Erie Total	432	94	95	1,019	1,640	57	1,583	14,940	20,240	S	
Niagara Falls	1,410	288	531	4,250	6,479	1,600	4,879	56,380	58,180	S	STAMFORD WPCP
Welland	1,040	70	238	1,451	2,799	405	2,394	35,340	45,460	S	WELLAND WPCP
Hamilton	5,646	654	844	4,927	12,071	4,430	7,641	310,570	409,140	S	WOODWARD AVE. WPCP
East York	1,520	53	230	323	2,126	1,596	530	35,460	45,460	S	NORTH TORONTO WPCP
Etobicoke	4,973	875	3,672	2,730	12,250	223	12,027	402,850	409,140	S	HUMBER WPCP
North York	9,810	437	3,930	3,510	17,687	134	17,553				
Scarborough	9,500	590	3,340	5,300	18,730	1,440	17,290	179,500	218,200	S	HIGHLAND CREEK WPCP
Toronto	6,800	535	2,380	0	9,715	7,286	2,429	779,020	818,280	S	MAIN WPCP
York	1,610	139	565	0	2,314	1,020	1,294				
Toronto Total	34,213	2,629	14,117	11,863	62,822	11,699	51,123	1,396,830	1,491,080	S	
Belleville	796	74	279	281	1,430	328	1,102	29,250	54,550	P	BELLEVILLE WPCP
Cornwall	1,300	241	298	582	2,421	605	1,816	49,430	54,550	P	CORNWALL WPCP
TOTAL	55,843	4,958	20,110	26,003	106,914	23,085	83,829	2,188,030	2,542,140		

References:

Catchment Data: Schroeter & Associates, 1991. Loadings of Toxic Contaminants from Urban Nonpoint Sources to the Great Lakes from Ontario Communities. Volume II - Appendices (6).
WPCP Data: Water Resources Branch, Ontario Ministry of the Environment. MOE Report on the 1989 Discharges from Municipal Sewage Treatment Plants in Ontario (7).

Notes:

1: P = Primary, S = Secondary
2: Fort Erie: Stevensville/Douglastown not included
3: Belleville: Peak Plant Capacity taken as 163,500 m3/d primary clarifier

TABLE 3.2
DERIVED INPUT DATA SUMMARY
ONTARIO RAP MUNICIPALITIES

Municipality	*CATCHMENT PARAMETERS*				*TREATMENT PARAMETERS*		
	Effective Area (ha)	*Runoff Coefficient*			*Net Plant Capacity for WWF (m3/d)*	*Net WWF Treatment Rate (mm/hr)*	*Plant Name*
		Comb.	*Separated*	*Overall*			
Thunder Bay	1,273	0.323	0.050	0.111	194,620	0.637	THUNDER BAY WPCP
Midland	281	0.332	0.050	0.166	22,850	0.339	MIDLAND WPCP
Sarnia	889	0.381	0.050	0.106	129,135	0.605	SARNIA WPCP
Windsor-East	598	0.362	0.050	0.080	53,180	0.371	LITTLE RIVER WPCP
Windsor-West	2,791	0.362	0.050	0.142	291,615	0.435	WESTERLY WPCP
Fort Erie (Anger Ave.)					30,210		ANGER AVE. WPCP
Fort Erie (Crystal B.)					5,450		CRYSTAL BEACH WPCP
Fort Erie Total	455	0.199	0.050	0.055	35,660	0.327	
Niagara Falls	2,862	0.193	0.050	0.085	89,070	0.130	STAMFORD WPCP
Welland	948	0.221	0.050	0.075	78,310	0.344	WELLAND WPCP
Hamilton	5,956	0.250	0.050	0.124	712,280	0.498	WOODWARD AVE. WPCP
East York	1,681	0.311	0.050	0.246	78,190	0.194	NORTH TORONTO WPCP
Etobicoke	1,937	0.351	0.050	0.055	620,000	1.334	HUMBER WPCP
North York	2,825	0.326	0.050	0.052			
Scarborough	4,338	0.298	0.050	0.069	366,000	0.352	HIGHLAND CREEK WPCP
Toronto	7,601	0.385	0.050	0.302	1,266,680	0.694	MAIN WPCP
York	1,187	0.386	0.050	0.198			
Toronto Total	19,363	0.334	0.050	0.103	2,330,870	0.502	
Belleville	496	0.328	0.050	0.114	134,250	1.127	BELLEVILLE WPCP
Cornwall	895	0.313	0.050	0.116	86,945	0.405	CORNWALL WPCP
TOTAL or AVERAGE	36,806	0.300	0.050	0.106	4,194,445	0.477	

Notes:

1: Effective Area is the effective combined area, or the total area multiplied by the ratio of overall to combined runoff coefficient.
2: Net WWF treatment rates are treatment capacity divided by the effective area.

flow at the WPCP. This net capacity is corrected to give net treatment rate by dividing by effective combined area. These and other assumptions are summarized in Table 3.3.

TABLE 3.3
ONTARIO RAP MUNICIPALITIES
MODELLING ASSUMPTIONS

Default Input Data:	
Maximum Depression Storage Capacity (mm):	2
Ratio of Peak Plant Capacity to Design Plant Capacity:	2.5
Net Wet Weather Flow Plant Capacity:	(Design Capacity X 2.5) - Dry Weather Flow
Runoff Coefficient for Pervious Areas:	0.05
Runoff Coefficient for Impervious Areas:	0.90

Land Use Parameters:	Percent Impervious		Cv	
	Combined Areas	Separated Areas	Combined Areas	Separated Areas
Residential	31%	0%	0.31	0.05
Commercial	62%	0%	0.58	0.05
Industrial	58%	0%	0.55	0.05
Open Space	4%	0%	0.08	0.05

The average interevent time for use in rainfall analysis was selected to be four hours in all cases. Rainfall data from the nearest meteorological station to each RAP site were used in the modelling.

Three CSO control criteria were employed in analysis. They included:

1. Cr - percent volumetric control.

2. Ns - number of overflows annually.

3. Cp - percent pollutant control for suspended solids (SS) and fecal coliforms (FC).

Each of the control criteria were applied to the analysis of two major combinations of technologies reflecting the current state-of-the-art in combined sewer management. The technologies considered included:

1. Storage - central treatment (WPCP).
2. Storage - satellite treatment - central treatment.

The satellite treatment train considered consisted of: a vortex separator, storage and disinfection by chlorination, followed by dechlorination to preclude effluent toxicity.

Chlorination-dechlorination was selected in preference to ultraviolet light irradiation because it represents a well demonstrated technology for CSO applications.

Table 3.4 presents pollutant removal efficiencies for both central and satellite treatment for all the RAP municipalities. Only suspended solids and fecal coliforms are considered in this study since these are common contaminants for which reliable data are available. They may also serve as indicators of removal of similar contaminants. For example, contaminants such as phosphorus and heavy metals are often physically bound to suspended solids in wastewater and may experience similar removal efficiencies.

The modified EXSUDS model was employed to produce storage-treatment performance isoquants and expansion paths. The expansion path cost and performance data were plotted to yield cost effectiveness curves for each municipality, and each control technology.

3.2 EXISTING LEVELS OF CONTROL

The modified EXSUDS model was used to estimate the following measures of control performance under existing conditions for each RAP municipality:

- Percent volumetric control
- Number of annual overflows
- Percent pollutant control for suspended solids and fecal coliforms.

Table 3.5 summarizes these existing levels of CSO control.

The control levels are reasonably narrowly distributed and range from 32 percent to 71 percent volumetric control with the preponderance of results in the 40 percent to 60 percent volumetric control range. The corresponding annual overflow frequencies range from a low of approximately 20 events to in excess of 50 events with the majority of municipalities clustered in the 30 to 40 event range.

Percentage pollution controls for suspended solids and fecal coliforms follow a similar pattern but reflect the combined effect of volumetric capture and differing process removal efficiencies among the various WPCPs (as documented in Table 3.4).

Despite these control levels, many of these municipalities have documented receiving water quality impairment due to CSOs and some further degree of control is desirable. In fact, the control levels indicated appear somewhat below expectations based upon PCP studies in Kingston, St. Catharines and Windsor (3, 4, 5), where more detailed STORM modelling gave volumetric control levels in the 50 to 75 percent range. A possible explanation is the choice of runoff coefficient for the combined sewer areas shown in Table 3.2. These may overstate the rainfall to runoff transformation and hence overstate CSO volumes. Another possible explanation is the fact that WPCP

TABLE 3.4
ONTARIO RAP MUNICIPALITIES
POLLUTION CONTROL PERFORMANCE DATA

Municipality Name	Plant Name	CENTRAL WPCP REMOVAL EFFICIENCIES	
		SS [%]	FC [%]
Thunder Bay	THUNDER BAY WPCP	*67%*	*99.99%*
Midland	MIDLAND WPCP	*96%*	*99.99%*
Sarnia	SARNIA WPCP	*86%*	*99.99%*
Windsor-East	LITTLE RIVER WPCP	*97%*	*99.99%*
Windsor-West	WESTERLY WPCP	*80%*	*99.99%*
Fort Erie (Anger Ave.)	ANGER AVE. WPCP	67%	99.99%
Fort Erie (Crystal B.)	CRYSTAL BEACH WPCP	78%	99.99%
Fort Erie Total		*72%*	*99.99%*
Niagara Falls	STAMFORD WPCP	*83%*	*99.99%*
Welland	WELLAND WPCP	*88%*	*99.99%*
Hamilton	WOODWARD AVE. WPCP	*96%*	*99.99%*
East York	NORTH TORONTO WPCP	91%	99.99%
Etobicoke	HUMBER WPCP	94%	99.99%
Scarborough	HIGHLAND CREEK WPCP	89%	99.99%
Toronto	MAIN WPCP	93%	99.99%
Toronto Total		*92%*	*99.99%*
Belleville	BELLEVILLE WPCP	*92%*	*99.99%*
Cornwall	CORNWALL WPCP	*84%*	*99.99%*

Municipality Name	Plant Name	ASSUMED SATELLITE TREATMENT REMOVAL EFFICIENCIES	
		SS [%]	FC [%]
Thunder Bay	THUNDER BAY WPCP	*30%*	*99.99%*
Midland	MIDLAND WPCP	*30%*	*99.99%*
Sarnia	SARNIA WPCP	*30%*	*99.99%*
Windsor-East	LITTLE RIVER WPCP	*30%*	*99.99%*
Windsor-West	WESTERLY WPCP	*30%*	*99.99%*
Fort Erie (Anger Ave.)	ANGER AVE. WPCP	30%	99.99%
Fort Erie (Crystal B.)	CRYSTAL BEACH WPCP	30%	99.99%
Fort Erie Total		*30%*	*99.99%*
Niagara Falls	STAMFORD WPCP	*30%*	*99.99%*
Welland	WELLAND WPCP	*30%*	*99.99%*
Hamilton	WOODWARD AVE. WPCP	*30%*	*99.99%*
East York	NORTH TORONTO WPCP	30%	99.99%
Etobicoke	HUMBER WPCP	30%	99.99%
Scarborough	HIGHLAND CREEK WPCP	30%	99.99%
Toronto	MAIN WPCP	30%	99.99%
Toronto Total		*30%*	*99.99%*
Belleville	BELLEVILLE WPCP	*30%*	*99.99%*
Cornwall	CORNWALL WPCP	*30%*	*99.99%*

References:

Water Resources Branch, Ontario Ministry of the Environment. MOE Report on the 1989 Discharges from Municipal Sewage Treatment Plants in Ontario

Notes:

Satellite Treatment: Vortex Separator with Disinfection by Chlorination/Dechlorination

TABLE 3.5
ONTARIO RAP MUNICIPALITIES
ESTIMATES OF EXISTING LEVELS OF CSO CONTROL

Municipality	Percent Volumetric Control	Annual Number of Overflows	Percent Pollutant Control - Suspended Solids	Percent Pollutant Control - Fecal Coliforms
Thunder Bay	58%	28	39%	58%
Midland	43%	39	41%	43%
Sarnia	50%	40	43%	50%
Windsor-East	39%	49	38%	39%
Windsor-West	43%	46	34%	43%
Fort Erie Total	53%	35	38%	53%
Niagara Falls	32%	51	26%	32%
Welland	52%	36	45%	52%
Hamilton	59%	34	57%	59%
Toronto Total	50%	30	46%	50%
Belleville	71%	20	66%	71%
Cornwall	49%	37	41%	49%

capacity for wet weather flow is underestimated since average dry weather flow is overestimated as noted in Section 3.1. Higher WPCP wet weather capacities would result in higher levels of volumetric control as noted in Kingston, St. Catharines and Windsor.

3.3 CENTRAL TREATMENT AND STORAGE

The modified EXSUDS model was used to develop performance and cost information on a control alternative involving storage with subsequent central treatment. Each municipality was examined separately for a wide range of values for each control criteria. The results obtained are presented in Table 3.6, for percent volumetric control, annual number of overflows and percent fecal coliform removal, and in Table 3.7 for percent suspended solids removal. These latter results are presented separately since not all plants are capable of reaching the control levels of 80 percent, 90 percent and 95 percent used in Table 3.6. This stems from the fact that the ultimate suspended solids removal is limited by the treatment efficiency of the WPCP.

These tables show incremental amounts of storage and treatment required above existing levels to meet the noted control levels. Thus, for example, in Windsor-East, an additional 14,591 m^3 of storage are required to meet 80 percent volumetric control, 30,170 m^3 are required to meet 90 percent volumetric control and 66,139 m^3 of storage along with 2,870 m^3/day of central treatment capacity are required to reach 95 percent volumetric control. In this sense, the tables depict the expansion paths for cost-effective increases in CSO control described in Section 2. All the expansion paths

TABLE 3.6
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
CENTRAL TREATMENT AND STORAGE

Municipality	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
	LEVEL OF VOLUMETRIC CONTROL					
	80%		90%		95%	
Thunder Bay	15,021	0	30,170	0	48,247	0
Midland	4,889	0	9,020	0	17,478	0
Sarnia	18,047	0	33,782	0	55,207	0
Windsor-East	14,591	0	27,030	0	66,139	2,870
Windsor-West	63,077	0	115,547	0	217,140	0
Fort Erie Total	4,004	0	7,644	0	12,194	0
Niagara Falls	39,496	0	79,850	0	137,090	41,213
Welland	9,575	0	18,107	0	29,104	0
Hamilton	54,795	0	114,355	0	184,040	0
Toronto Total	309,808	0	571,209	0	894,571	0
Belleville	2,926	0	8,680	0	14,781	0
Cornwall	13,694	0	25,418	0	42,065	0
Total	549,923	0	1,040,812	0	1,718,055	44,083
	ANNUAL NUMBER OF OVERFLOWS					
	10		3		1	
Thunder Bay	20,877	0	51,175	0	112,024	39,718
Midland	6,688	0	25,318	674	25,318	28,325
Sarnia	28,448	0	70,853	0	103,124	113,081
Windsor-East	22,604	0	64,345	18,658	76,006	96,158
Windsor-West	97,127	0	252,865	60,286	291,939	448,793
Fort Erie Total	6,097	0	14,196	0	30,349	16,380
Niagara Falls	58,671	0	133,369	68,688	174,010	240,408
Welland	14,504	0	34,223	0	69,583	43,229
Hamilton	98,274	0	228,115	0	510,429	257,299
Toronto Total	381,451	0	902,316	0	2,114,440	557,654
Belleville	5,555	0	16,021	0	27,974	0
Cornwall	19,959	0	50,210	0	74,912	75,180
Total	760,255	0	1,843,004	148,306	3,610,107	1,916,225
	LEVEL OF FECAL COLIFORM REMOVAL					
	80%		90%		95%	
Thunder Bay	15,021	0	30,170	0	48,247	0
Midland	4,889	0	9,020	0	17,534	0
Sarnia	18,047	0	33,782	0	55,296	0
Windsor-East	14,591	0	27,030	0	66,079	2,870
Windsor-West	63,077	0	115,827	0	217,698	0
Fort Erie Total	4,004	0	7,644	0	12,194	0
Niagara Falls	39,496	0	80,136	0	137,090	41,213
Welland	9,575	0	18,107	0	29,198	0
Hamilton	54,795	0	114,355	0	184,636	0
Toronto Total	309,808	0	573,145	0	896,507	0
Belleville	2,926	0	8,730	0	14,781	0
Cornwall	13,694	0	25,508	0	42,065	0
Total	549,923	0	1,043,452	0	1,721,325	44,083

TABLE 3.7
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
CENTRAL TREATMENT AND STORAGE
(% SUSPENDED SOLIDS REMOVAL)

Percent Suspended Solids Removal	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
Thunder Bay		
50	10,057	0
60	29,279	0
65	68,233	0
Midland		
80	5,873	0
90	13,460	0
95	29,505	39,115
Sarnia		
70	19,647	0
80	43,739	0
85	106,769	123,749
Windsor-East		
80	16,624	0
90	36,538	0
95	71,939	54,538
Windsor-West		
75	170,809	0
77	252,865	53,587
79	291,939	448,793
Fort Erie Total		
50	1,957	0
60	4,914	0
70	20,020	0
Niagara Falls		
70	50,085	0
80	148,538	82,426
82	175,441	261,014
Welland		
80	19,434	0
85	39,247	0
87	70,152	56,880
Hamilton		
80	70,281	0
90	160,216	0
95	519,959	357,360
Toronto Total		
70	245,910	0
80	466,648	0
90	2,199,637	46,471
Belleville		
70	1,438	0
80	6,448	0
90	23,114	0
Cornwall		
70	16,737	0
80	44,482	0
82	69,810	25,776

depicted in the tables show a similar trend. At lower levels of control, storage solutions are recommended. At higher control levels, a blend of technologies using combinations of storage and treatment are recommended as optimal solutions.

Table 3.8 presents the total capital costs for the recommended central treatment-storage solutions using the Cr, Ns, Cp-FC and Cp-SS control criteria. Note, however, that these optimal solutions are arrived at by considering both capital and annual operation and maintenance costs. As noted in Section 2.2.6, the components included in operation and maintenance costs, as well as assumptions made regarding annualization of costs, were provided in a previous report (Ref. 1). Aggregate capital cost estimates have been prepared for all municipalities and all control measures except Cp-SS and are plotted as cost-effectiveness curves in Figure 3.1.

Table 3.9 presents these same costs on a per unit effective combined sewer area basis (i.e., $/hectare). Unit area costs are relatively uniform across all municipalities with Midland, Windsor-East and Fort Erie as exceptions. A possible explanation for these higher unit costs is that these are municipalities with relatively small effective combined sewer areas in combination with lower levels of existing control. In these instances, economies of scale are not realized.

Aggregate costs were not prepared for Cp-SS because of the highly variable WPCP efficiencies for solids removal which yield correspondingly different Cp-SS upper limits for each WPCP. This does not permit aggregation of costs for all WPCPs for a given level of control since not all WPCPs may achieve this level. The shaded areas of Table 3.8 indicate where a plant is unable to achieve the levels noted. Costs escalate sharply as this limit is approached since, in reality, all CSO flows must be treated at the WPCP to achieve this limit.

The impact of the initial control levels (presented in Table 3.5) upon the final aggregate costs, sections, particularly at the higher control levels, is small. The incremental cost of achieving initial improvements in control level (for example from 50 percent volumetric control to 70 percent volumetric control) is quite low in comparison to the incremental costs of achieving very high control levels (e.g. 95 percent volumetric control).

Two common control measures can be used to illustrate the magnitude of required costs. The estimated cost to achieve one overflow annually for all RAP municipalities with CSO is in excess of $2.4 billion while the estimated cost to achieve 90 percent volumetric control is over $440 million. Based on these preliminary estimates, it is apparent that very considerable expenditures will be required to fully address wet weather flow problems.

TABLE 3.8
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$220,000	$0	$0	$2,660,000	$0	$0	$0	$0	$0	$2,890,000
50	$0	$620,000	$0	$2,020,000	$4,690,000	$0	$6,200,000	$0	$0	$0	$0	$420,000	$13,940,000
60	$920,000	$1,570,000	$3,040,000	$4,160,000	$11,870,000	$750,000	$10,480,000	$1,650,000	$720,000	$28,210,000	$0	$2,770,000	$66,130,000
70	$4,720,000	$2,770,000	$6,760,000	$6,880,000	$20,890,000	$1,950,000	$15,990,000	$3,990,000	$11,800,000	$63,710,000	$0	$5,710,000	$145,160,000
80	$9,820,000	$4,420,000	$11,810,000	$10,680,000	$33,340,000	$3,570,000	$24,000,000	$7,150,000	$26,680,000	$111,530,000	$2,240,000	$9,710,000	$254,950,000
90	$18,060,000	$7,360,000	$20,250,000	$17,690,000	$55,290,000	$6,220,000	$41,880,000	$12,360,000	$50,750,000	$189,530,000	$6,070,000	$16,430,000	$441,900,000
95	$27,480,000	$12,540,000	$31,060,000	$42,530,000	$92,190,000	$9,390,000	$122,100,000	$18,720,000	$78,280,000	$281,500,000	$10,050,000	$25,240,000	$751,090,000
97	$37,160,000	$33,990,000	$49,790,000	$82,960,000	$128,230,000	$13,160,000	$198,550,000	$26,980,000	$106,730,000	$385,660,000	$13,380,000	$42,680,000	$1,119,290,000
99	$85,350,000	$83,130,000	$84,500,000	$187,850,000	$227,850,000	$61,630,000	$392,260,000	$119,560,000	$455,350,000	$1,417,450,000	$21,300,000	$70,390,000	$3,206,630,000
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$680,000	$0	$0	$0	$0	$0	$680,000
40	$0	$0	$0	$1,920,000	$4,690,000	$0	$4,790,000	$0	$0	$0	$0	$0	$11,410,000
30	$0	$1,100,000	$3,720,000	$4,570,000	$13,520,000	$750,000	$10,010,000	$1,650,000	$5,380,000	$0	$0	$2,340,000	$43,040,000
20	$4,150,000	$2,680,000	$8,670,000	$8,220,000	$25,580,000	$2,330,000	$17,380,000	$4,740,000	$20,100,000	$46,860,000	$0	$6,220,000	$146,930,000
10	$12,060,000	$5,320,000	$16,780,000	$14,660,000	$46,140,000	$4,890,000	$31,470,000	$9,740,000	$43,700,000	$120,630,000	$3,720,000	$12,570,000	$321,700,000
5	$20,660,000	$8,810,000	$26,500,000	$25,550,000	$74,740,000	$7,780,000	$87,350,000	$15,470,000	$70,020,000	$201,310,000	$7,610,000	$20,130,000	$565,940,000
3	$28,480,000	$18,990,000	$38,140,000	$66,350,000	$123,770,000	$10,690,000	$155,160,000	$21,450,000	$95,470,000	$275,970,000	$10,790,000	$28,980,000	$874,240,000
1	$66,870,000	$60,810,000	$81,260,000	$162,320,000	$206,470,000	$48,380,000	$330,100,000	$95,530,000	$386,820,000	$911,370,000	$17,610,000	$62,400,000	$2,429,950,000
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$230,000	$0	$0	$2,660,000	$0	$0	$0	$0	$0	$2,890,000
50	$0	$620,000	$0	$2,020,000	$4,690,000	$0	$6,200,000	$0	$0	$0	$0	$420,000	$13,940,000
60	$930,000	$1,570,000	$3,040,000	$4,170,000	$11,870,000	$750,000	$10,480,000	$1,650,000	$730,000	$28,220,000	$0	$2,770,000	$66,170,000
70	$4,720,000	$2,770,000	$6,760,000	$6,880,000	$20,890,000	$1,950,000	$16,000,000	$3,990,000	$11,810,000	$63,730,000	$0	$5,710,000	$145,220,000
80	$9,830,000	$4,420,000	$11,810,000	$10,680,000	$33,350,000	$3,570,000	$24,010,000	$7,150,000	$26,700,000	$111,570,000	$2,240,000	$9,710,000	$255,050,000
90	$18,070,000	$7,360,000	$20,260,000	$17,700,000	$55,320,000	$6,220,000	$41,910,000	$12,370,000	$50,780,000	$189,630,000	$6,080,000	$16,440,000	$442,150,000
95	$27,500,000	$12,570,000	$31,090,000	$42,690,000	$92,370,000	$9,400,000	$122,330,000	$18,740,000	$78,360,000	$281,750,000	$10,060,000	$25,270,000	$752,130,000
97	$37,230,000	$34,110,000	$50,080,000	$83,550,000	$128,760,000	$13,190,000	$199,310,000	$27,060,000	$106,930,000	$386,470,000	$13,400,000	$42,760,000	$1,122,850,000
99	$85,730,000	$83,900,000	$85,010,000	$188,950,000	$228,650,000	$62,080,000	$394,110,000	$120,380,000	$459,190,000	$1,427,140,000	$21,390,000	$70,820,000	$3,227,360,000

TABLE 3.8 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,570,000	$0	$0	$0	$0	$0	$1,570,000
40	$810,000	$0	$0	$480,000	$4,690,000	$310,000	$5,490,000	$0	$0	$0	$0	$0	$11,780,000
50	$6,390,000	$780,000	$2,540,000	$2,360,000	$13,520,000	$1,790,000	$10,390,000	$1,080,000	$0	$13,200,000	$0	$2,500,000	$54,550,000
60	$16,290,000	$1,810,000	$6,640,000	$4,640,000	$25,580,000	$4,040,000	$17,070,000	$3,520,000	$3,810,000	$46,890,000	$0	$5,940,000	$136,230,000
65	$33,590,000												
70		$3,140,000	$12,500,000	$7,590,000	$46,130,000	$12,230,000	$28,400,000	$6,900,000	$16,100,000	$91,240,000	$1,280,000	$11,040,000	
75					$74,740,000								
77					$123,750,000								
79					$206,440,000								
80		$5,110,000	$24,350,000	$11,910,000			$153,890,000	$12,850,000	$33,480,000	$159,260,000	$4,700,000	$24,280,000	
82							$331,700,000					$47,060,000	
85			$79,550,000					$22,980,000					
87								$107,880,000					
90		$9,860,000		$22,090,000					$67,040,000	$572,820,000	$13,560,000		
95		$72,320,000		$106,310,000					$431,220,000				

Figure 3.1
ONTARIO RAP SITE AGGREGATE COST EFFECTIVENESS CURVES
Central Treatment & Storage

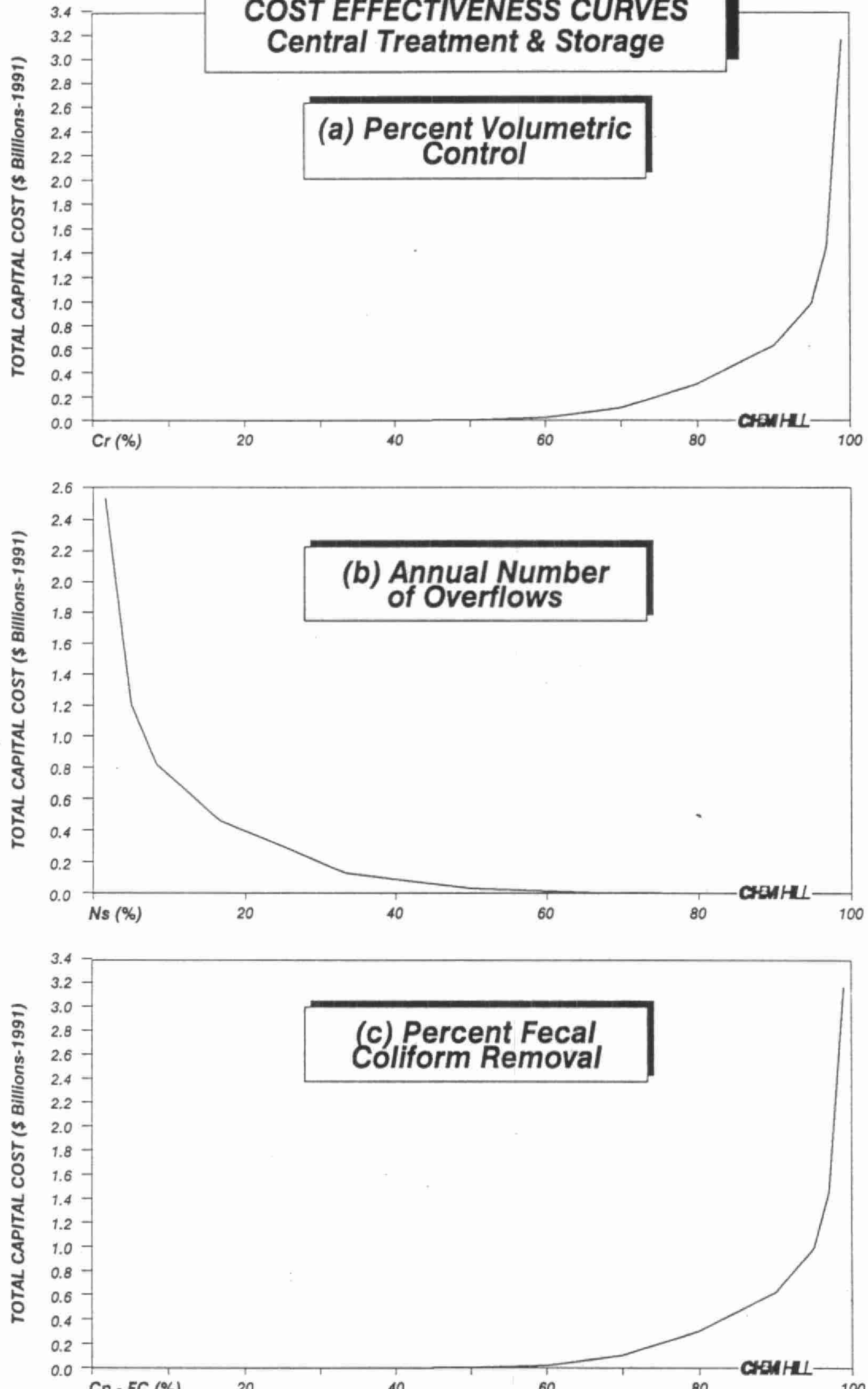

TABLE 3.9
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$800	$0	$0	$1,700	$0	$0	$0	$0	$0	$100
50	$0	$2,700	$0	$7,800	$2,200	$0	$3,900	$0	$0	$0	$0	$700	$600
60	$1,100	$6,800	$5,600	$16,000	$5,700	$13,200	$6,600	$4,100	$200	$2,400	$0	$4,600	$2,900
70	$5,700	$12,000	$12,500	$26,500	$9,900	$34,200	$10,000	$9,900	$2,700	$5,400	$0	$9,400	$6,300
80	$11,800	$19,100	$21,900	$41,100	$15,900	$62,600	$15,000	$17,700	$6,000	$9,500	$6,800	$16,000	$11,000
90	$21,800	$31,900	$37,500	$68,000	$26,300	$109,100	$26,200	$30,500	$11,500	$16,200	$18,500	$27,200	$19,100
95	$33,100	$54,300	$57,500	$163,600	$43,900	$164,700	$76,300	$46,200	$17,700	$24,100	$30,600	$41,700	$32,500
97	$44,800	$147,100	$92,200	$319,100	$61,100	$230,900	$124,100	$66,600	$24,100	$33,000	$40,800	$70,500	$48,500
99	$102,800	$359,900	$156,500	$722,500	$108,500	$1,081,200	$245,200	$295,200	$102,800	$121,200	$64,900	$116,300	$138,900
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$400	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$7,400	$2,200	$0	$3,000	$0	$0	$0	$0	$0	$500
30	$0	$4,800	$6,900	$17,600	$6,400	$13,200	$6,300	$4,100	$1,200	$0	$0	$3,900	$1,900
20	$5,000	$11,600	$16,100	$31,600	$12,200	$40,900	$10,900	$11,700	$4,500	$4,000	$0	$10,300	$6,400
10	$14,500	$23,000	$31,100	$56,400	$22,000	$85,800	$19,700	$24,000	$9,900	$10,300	$11,300	$20,800	$13,900
5	$24,900	$38,100	$49,100	$98,300	$35,600	$136,500	$54,600	$38,200	$15,800	$17,200	$23,200	$33,300	$24,500
3	$34,300	$82,200	$70,600	$255,200	$58,900	$187,500	$97,000	$53,000	$21,600	$23,600	$32,900	$47,900	$37,900
1	$80,600	$263,200	$150,500	$624,300	$98,300	$848,800	$206,300	$235,900	$87,300	$77,900	$53,700	$103,100	$105,300
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$900	$0	$0	$1,700	$0	$0	$0	$0	$0	$100
50	$0	$2,700	$0	$7,800	$2,200	$0	$3,900	$0	$0	$0	$0	$700	$600
60	$1,100	$6,800	$5,600	$16,000	$5,700	$13,200	$6,600	$4,100	$200	$2,400	$0	$4,600	$2,900
70	$5,700	$12,000	$12,500	$26,500	$9,900	$34,200	$10,000	$9,900	$2,700	$5,400	$0	$9,400	$6,300
80	$11,800	$19,100	$21,900	$41,100	$15,900	$62,600	$15,000	$17,700	$6,000	$9,500	$6,800	$16,000	$11,000
90	$21,800	$31,900	$37,500	$68,100	$26,300	$109,100	$26,200	$30,500	$11,500	$16,200	$18,500	$27,200	$19,200
95	$33,100	$54,400	$57,600	$164,200	$44,000	$164,900	$76,500	$46,300	$17,700	$24,100	$30,700	$41,800	$32,600
97	$44,900	$147,700	$92,700	$321,300	$61,300	$231,400	$124,600	$66,800	$24,100	$33,000	$40,900	$70,700	$48,600
99	$103,300	$363,200	$157,400	$726,700	$108,900	$1,089,100	$246,300	$297,200	$103,700	$122,000	$65,200	$117,100	$139,800

TABLE 3.9 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
CENTRAL TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,000	$0	$0	$0	$0	$0	$100
40	$1,000	$0	$0	$1,800	$2,200	$5,400	$3,400	$0	$0	$0	$0	$0	$500
50	$7,700	$3,400	$4,700	$9,100	$6,400	$31,400	$6,500	$2,700	$0	$1,100	$0	$4,100	$2,400
60	$19,600	$7,800	$12,300	$17,800	$12,200	$70,900	$10,700	$8,700	$900	$4,000	$0	$9,800	$5,900
65	$40,500												
70		$13,600	$23,100	$29,200	$22,000	$214,600	$17,800	$17,000	$3,600	$7,800	$3,900	$18,200	
75					$35,600								
77					$58,900								
79					$98,300								
80		$22,100	$45,100	$45,800			$96,200	$31,700	$7,600	$13,600	$14,300	$40,100	
82							$207,300					$77,800	
85			$147,300					$56,700					
87								$266,400					
90		$42,700		$85,000					$15,100	$49,000	$41,300		
95		$313,100		$408,900					$97,300				

3.4 SATELLITE TREATMENT AND STORAGE

The results of cost optimization for satellite treatment and storage are presented in Tables 3.10 for Cr, Ns, Cp-FC and Table 3.11 for Cp-SS. Examination of results for percent volumetric control and annual number of overflows, where treatment removal efficiencies play no role, indicates that the lower cost of satellite treatment yields more balanced control strategies comprised of storage and treatment combinations. This is in clear contrast to the central treatment case (Section 3.3) where due to cost, storage alone was preferred until the highest control levels.

The impact of pollutant removal efficiency upon the solution can be assessed by comparing the results in Tables 3.10 for percent fecal coliform control and Table 3.11 for percent suspended solids control. In the case of fecal coliforms, the satellite treatment process efficiencies are high and balanced solutions of storage and treatment are preferred. In the case of suspended solids, process efficiencies are lower and in this instance storage is often the preferred solution.

It is noteworthy that in a number of cases, an increment of satellite treatment rather than storage is added as the first step on the expansion path of cost-effective technologies. This result is of interest since conventional thinking in CSO control has tended to favour the technologically simpler option of storage as a first line of attack in addressing CSO problems.

Capital cost estimates reflecting the expansion paths for Cr, Ns, Cp-FC and Cp-SS are presented in Table 3.12. Costs have been, once again, aggregated only for Cr, Ns and Cp-FC. Treatment for the existing levels of control is assumed to be provided by the central WPCP. The combination of central and satellite treatment therefore yields different upper Cp-SS limits for each municipality which does not permit simple aggregation of costs. Once again, the shaded areas of the table indicate those plants not capable of achieving the noted control levels, and costs escalate sharply as these limits are approached. Figure 3.2 presents the cost effectiveness curves for Cr, Ns and Cp-FC respectively using satellite treatment and storage.

Table 3.13 presents these same costs on a per unit effective combined sewer area basis (i.e., $/hectare). Once again, unit area costs are generally uniform across the various municipalities. These unit costs are less variable than those for central treatment and storage, probably reflecting the fact that none of municipalities currently have satellite treatment and that its costs are the same on a flowrate basis for all municipalities.

The impact of the initial control levels (presented in Table 3.5) upon the final aggregate costs, sections, particularly at the higher control levels, is small. The incremental cost of achieving initial improvements in control level (for example from 50 percent volumetric control to 70 percent volumetric control) is quite low in comparison to the incremental costs of achieving very high control levels (e.g. 95 percent volumetric control).

TABLE 3.10
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
SATELLITE TREATMENT AND STORAGE

Municipality	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
	LEVEL OF VOLUMETRIC CONTROL					
	80%		90%		95%	
Thunder Bay	0	366,624	0	1,069,320	14,003	1,084,596
Midland	0	97,788	3,091	99,137	6,210	100,486
Sarnia	0	388,315	0	1,032,662	13,335	1,045,464
Windsor-East	0	276,994	0	688,896	8,492	697,507
Windsor-West	0	1,252,601	0	3,175,042	0	7,026,622
Fort Erie Total	0	89,544	3,231	90,636	6,507	92,820
Niagara Falls	0	680,011	0	1,634,774	0	3,551,170
Welland	0	211,594	0	575,626	7,394	582,451
Hamilton	0	1,200,730	0	3,616,483	0	8,433,696
Toronto Total	0	6,831,266	0	18,309,653	0	41,219,954
Belleville	0	79,757	0	347,597	5,704	352,358
Cornwall	0	279,240	0	736,764	9,845	743,208
Total	0	11,754,463	6,322	31,376,590	71,490	64,930,332
	ANNUAL NUMBER OF OVERFLOWS					
	10		3		1	
Thunder Bay	0	583,543	10,311	1,518,434	32,334	1,536,766
Midland	0	154,438	5,339	158,484	10,453	159,833
Sarnia	0	774,497	9,779	1,828,495	30,848	1,847,698
Windsor-East	0	523,848	14,771	536,765	28,704	542,506
Windsor-West	0	2,404,726	0	9,598,807	62,798	9,692,585
Fort Erie Total	0	168,168	5,551	172,536	10,875	174,720
Niagara Falls	0	1,153,958	14,310	2,617,013	45,506	2,644,488
Welland	0	393,610	12,893	402,710	25,122	407,261
Hamilton	0	2,815,997	0	12,178,829	85,766	12,307,478
Toronto Total	0	9,294,240	0	41,824,080	0	134,720,009
Belleville	0	179,750	9,920	185,702	19,344	189,274
Cornwall	0	485,448	7,250	1,164,216	22,823	1,174,956
Total	0	18,932,222	90,123	72,186,072	374,572	165,397,572
	LEVEL OF FECAL COLIFORM REMOVAL					
	80%		90%		95%	
Thunder Bay	0	366,624	0	1,072,375	0	2,480,822
Midland	0	97,788	3,119	99,137	6,266	100,486
Sarnia	0	388,315	0	1,034,796	0	2,329,891
Windsor-East	0	276,994	0	690,331	8,611	697,507
Windsor-West	0	1,252,601	0	3,181,740	0	7,040,018
Fort Erie Total	0	89,544	3,276	90,636	6,552	92,820
Niagara Falls	0	680,011	0	1,634,774	0	3,558,038
Welland	0	211,594	0	575,626	7,584	582,451
Hamilton	0	1,215,024	0	3,630,778	0	8,462,285
Toronto Total	0	6,831,266	0	18,309,653	0	41,312,897
Belleville	0	79,757	0	347,597	5,803	352,358
Cornwall	0	279,240	0	736,764	10,024	745,356
Total	0	11,768,758	6,395	31,404,206	44,841	67,754,930

TABLE 3.11
ONTARIO RAP MUNICIPALITIES
EXPANSION PATHS FOR
SATELLITE TREATMENT AND STORAGE
(% SUSPENDED SOLIDS REMOVAL)

Percent Suspended Solids Removal	Additional Storage Required (over existing) (m3)	Additional Treatment Required (over existing) (m3/d)
Thunder Bay		
50	10,311	0
60	29,661	0
65	69,888	0
Midland		
70	3,428	0
80	5,957	0
90	13,994	0
Sarnia		
70	19,914	0
80	44,450	0
82	60,185	0
Windsor-East		
70	10,106	0
80	16,923	0
90	38,332	0
Windsor-West		
70	86,800	355,015
75	147,644	361,714
77	250,911	368,412
Fort Erie Total		
50	2,002	0
60	5,005	0
70	21,112	0
Niagara Falls		
60	27,761	0
70	51,230	0
75	89,008	0
Welland		
70	9,480	0
80	19,718	0
85	40,954	0
Hamilton		
90	153,069	414,538
92	198,335	414,538
94	333,536	428,832
Toronto Total		
70	220,738	1,626,492
80	437,604	1,672,963
90	1,624,556	1,719,434
Belleville		
70	1,488	0
80	6,547	0
90	23,362	0
Cornwall		
60	8,503	0
70	16,916	0
80	45,645	0

TABLE 3.12
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Winsdor East	Winsdor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$60,000	$0	$0	$460,000	$0	$0	$0	$0	$0	$530,000
50	$0	$160,000	$0	$440,000	$830,000	$0	$1,110,000	$0	$0	$0	$0	$110,000	$2,640,000
60	$260,000	$410,000	$650,000	$920,000	$2,160,000	$210,000	$1,950,000	$400,000	$0	$4,150,000	$0	$630,000	$11,750,000
70	$1,220,000	$760,000	$1,560,000	$1,600,000	$4,010,000	$570,000	$3,120,000	$1,020,000	$2,140,000	$10,080,000	$0	$1,360,000	$27,450,000
80	$2,730,000	$1,310,000	$2,980,000	$2,660,000	$6,920,000	$1,140,000	$4,970,000	$2,000,000	$5,510,000	$19,390,000	$750,000	$2,500,000	$52,870,000
90	$5,820,000	$3,700,000	$5,910,000	$4,850,000	$12,880,000	$3,600,000	$8,750,000	$4,010,000	$12,400,000	$38,470,000	$2,390,000	$4,830,000	$107,590,000
95	$13,730,000	$6,100,000	$13,530,000	$10,210,000	$22,240,000	$6,090,000	$14,680,000	$8,830,000	$23,230,000	$68,450,000	$6,310,000	$10,830,000	$204,240,000
97	$19,960,000	$8,060,000	$19,520,000	$14,420,000	$36,730,000	$8,110,000	$23,020,000	$12,630,000	$36,300,000	$104,610,000	$9,390,000	$15,560,000	$308,290,000
99	$27,550,000	$9,770,000	$26,700,000	$22,210,000	$59,770,000	$9,870,000	$37,880,000	$19,630,000	$69,760,000	$207,940,000	$15,070,000	$24,280,000	$530,430,000
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$140,000	$0	$0	$0	$0	$0	$140,000
40	$0	$0	$0	$390,000	$830,000	$0	$840,000	$0	$0	$0	$0	$0	$2,060,000
30	$0	$260,000	$780,000	$970,000	$2,430,000	$210,000	$1,820,000	$400,000	$1,090,000	$0	$0	$500,000	$8,470,000
20	$1,000,000	$700,000	$2,020,000	$1,900,000	$4,950,000	$680,000	$3,340,000	$1,210,000	$4,080,000	$6,730,000	$0	$1,420,000	$28,030,000
10	$3,340,000	$1,580,000	$4,540,000	$3,780,000	$10,100,000	$1,640,000	$6,480,000	$2,880,000	$10,200,000	$20,520,000	$1,270,000	$3,320,000	$69,640,000
5	$7,010,000	$3,980,000	$8,510,000	$9,120,000	$18,200,000	$4,120,000	$11,400,000	$7,680,000	$19,810,000	$42,180,000	$5,160,000	$6,300,000	$143,460,000
3	$13,320,000	$5,870,000	$14,620,000	$13,330,000	$27,960,000	$6,080,000	$19,660,000	$11,450,000	$31,410,000	$68,310,000	$8,230,000	$11,100,000	$231,330,000
1	$24,650,000	$9,400,000	$25,550,000	$21,150,000	$54,070,000	$9,720,000	$34,460,000	$18,500,000	$64,740,000	$142,980,000	$13,960,000	$19,700,000	$438,900,000
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$60,000	$0	$0	$460,000	$0	$0	$0	$0	$0	$530,000
50	$0	$160,000	$0	$440,000	$830,000	$0	$1,110,000	$0	$0	$0	$0	$110,000	$2,650,000
60	$270,000	$410,000	$650,000	$920,000	$2,160,000	$210,000	$1,950,000	$400,000	$200,000	$4,150,000	$0	$630,000	$11,950,000
70	$1,230,000	$760,000	$1,560,000	$1,600,000	$4,010,000	$570,000	$3,120,000	$1,020,000	$2,340,000	$10,080,000	$0	$1,360,000	$27,660,000
80	$2,730,000	$1,310,000	$2,990,000	$2,670,000	$6,920,000	$1,140,000	$4,970,000	$2,010,000	$5,710,000	$19,400,000	$750,000	$2,500,000	$53,090,000
90	$5,820,000	$3,720,000	$5,910,000	$4,850,000	$12,880,000	$3,630,000	$8,750,000	$4,010,000	$12,610,000	$38,490,000	$2,390,000	$4,830,000	$107,910,000
95	$10,690,000	$6,130,000	$10,510,000	$10,270,000	$22,270,000	$6,120,000	$14,700,000	$8,890,000	$23,460,000	$68,530,000	$6,350,000	$10,900,000	$198,820,000
97	$17,180,000	$8,090,000	$16,760,000	$14,490,000	$36,980,000	$8,140,000	$23,170,000	$12,690,000	$36,580,000	$104,820,000	$9,440,000	$15,640,000	$303,990,000
99	$28,630,000	$12,070,000	$27,780,000	$22,320,000	$63,000,000	$12,210,000	$38,100,000	$19,730,000	$70,410,000	$209,040,000	$15,150,000	$24,410,000	$542,870,000

TABLE 3.12 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY FOR
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Winsdor East	Winsdor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$1,630,000	$0	$0	$0	$0	$0	$1,630,000
40	$900,000	$0	$0	$520,000	$1,910,000	$330,000	$5,580,000	$0	$0	$0	$0	$0	$9,240,000
50	$6,520,000	$790,000	$2,590,000	$2,420,000	$10,920,000	$1,820,000	$10,530,000	$1,120,000	$0	$5,200,000	$0	$2,540,000	$44,450,000
60	$16,470,000	$1,830,000	$6,730,000	$4,730,000	$22,930,000	$4,090,000	$17,290,000	$3,590,000	$2,050,000	$39,870,000	$0	$6,010,000	$125,590,000
65	$34,210,000												
70		$3,180,000	$12,640,000	$7,710,000	$42,740,000	$12,710,000	$28,860,000	$6,990,000	$14,730,000	$84,740,000	$1,320,000	$11,150,000	
75					$67,550,000		$45,760,000						
77					$105,090,000								
80		$5,170,000	$24,670,000	$12,100,000				$13,010,000	$32,320,000	$152,660,000	$4,760,000	$24,760,000	
82			$33,110,000										
85								$23,710,000					
90		$10,140,000		$22,880,000					$65,580,000	$410,270,000	$13,690,000		
92									$85,210,000				
94									$131,630,000				

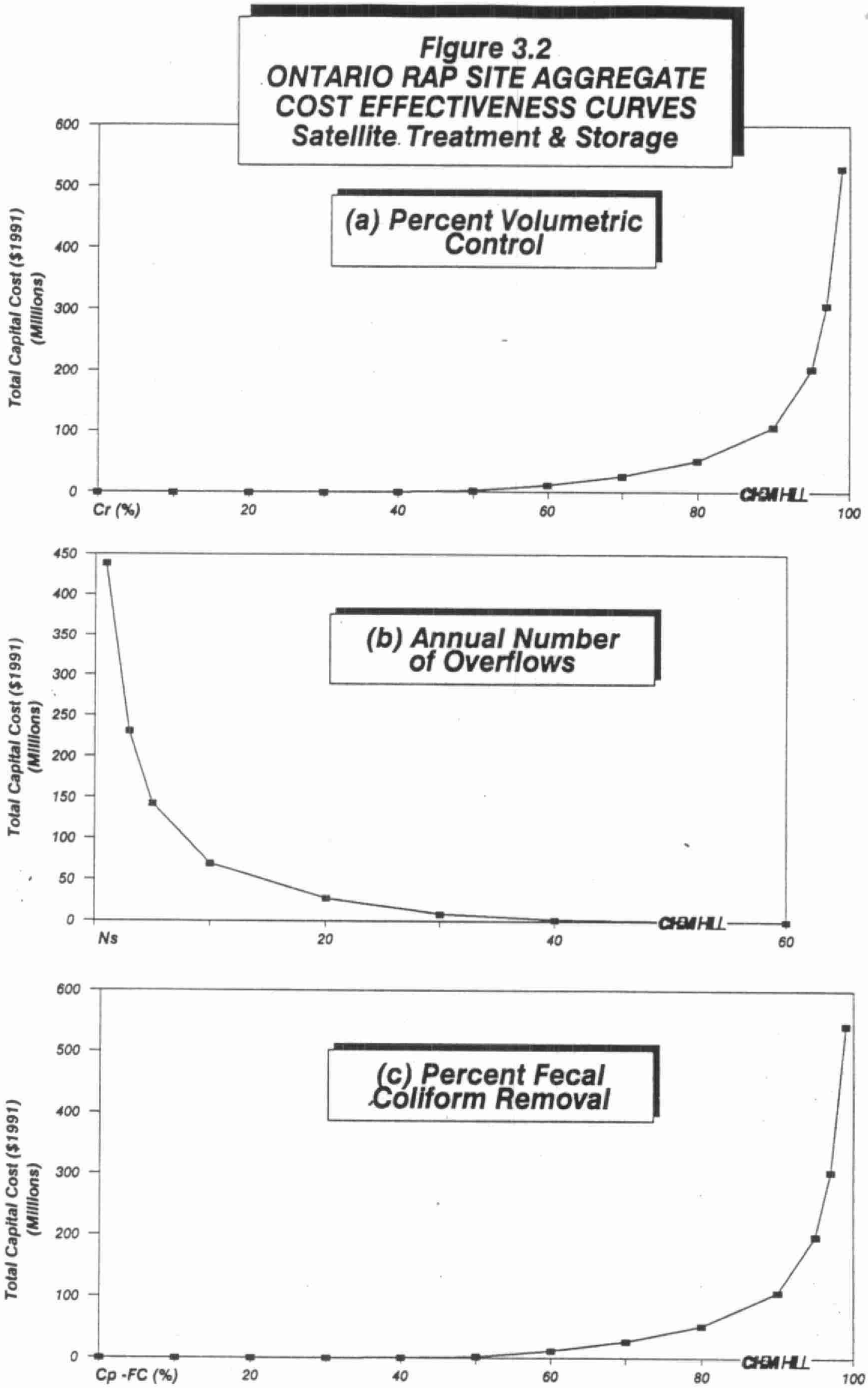

Figure 3.2
ONTARIO RAP SITE AGGREGATE COST EFFECTIVENESS CURVES
Satellite Treatment & Storage

TABLE 3.13
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Volumetric Control													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$100	$0	$0	$200	$0	$0	$0	$0	$0	$0
50	$0	$600	$0	$700	$300	$0	$400	$0	$0	$0	$0	$100	$100
60	$200	$1,500	$700	$1,500	$800	$500	$700	$400	$0	$200	$0	$700	$300
70	$1,000	$2,700	$1,800	$2,700	$1,400	$1,300	$1,100	$1,100	$400	$500	$0	$1,500	$700
80	$2,100	$4,700	$3,400	$4,400	$2,500	$2,500	$1,700	$2,100	$900	$1,000	$1,500	$2,800	$1,400
90	$4,600	$13,200	$6,600	$8,100	$4,600	$7,900	$3,100	$4,200	$2,100	$2,000	$4,800	$5,400	$2,900
95	$10,800	$21,700	$15,200	$17,100	$8,000	$13,400	$5,100	$9,300	$3,900	$3,500	$12,700	$12,100	$5,500
97	$15,700	$28,700	$22,000	$24,100	$13,200	$17,800	$8,000	$13,300	$6,100	$5,400	$18,900	$17,400	$8,400
99	$21,600	$34,800	$30,000	$37,100	$21,400	$21,700	$13,200	$20,700	$11,700	$10,700	$30,400	$27,100	$14,400
Annual Number of Overflows													
60	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
50	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$700	$300	$0	$300	$0	$0	$0	$0	$0	$100
30	$0	$900	$900	$1,600	$900	$500	$600	$400	$200	$0	$0	$600	$200
20	$800	$2,500	$2,300	$3,200	$1,800	$1,500	$1,200	$1,300	$700	$300	$0	$1,600	$800
10	$2,600	$5,600	$5,100	$6,300	$3,600	$3,600	$2,300	$3,000	$1,700	$1,100	$2,600	$3,700	$1,900
5	$5,500	$14,200	$9,600	$15,300	$6,500	$9,100	$4,000	$8,100	$3,300	$2,200	$10,400	$7,000	$3,900
3	$10,500	$20,900	$16,400	$22,300	$10,000	$13,400	$6,900	$12,100	$5,300	$3,500	$16,600	$12,400	$6,300
1	$19,400	$33,500	$28,700	$35,400	$19,400	$21,400	$12,000	$19,500	$10,900	$7,400	$28,100	$22,000	$11,900
Percent Fecal Coliform Removal													
30	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
40	$0	$0	$0	$100	$0	$0	$200	$0	$0	$0	$0	$0	$0
50	$0	$600	$0	$700	$300	$0	$400	$0	$0	$0	$0	$100	$100
60	$200	$1,500	$700	$1,500	$800	$500	$700	$400	$0	$200	$0	$700	$300
70	$1,000	$2,700	$1,800	$2,700	$1,400	$1,300	$1,100	$1,100	$400	$500	$0	$1,500	$800
80	$2,100	$4,700	$3,400	$4,500	$2,500	$2,500	$1,700	$2,100	$1,000	$1,000	$1,500	$2,800	$1,400
90	$4,600	$13,200	$6,600	$8,100	$4,600	$8,000	$3,100	$4,200	$2,100	$2,000	$4,800	$5,400	$2,900
95	$8,400	$21,800	$11,800	$17,200	$8,000	$13,500	$5,100	$9,400	$3,900	$3,500	$12,800	$12,200	$5,400
97	$13,500	$28,800	$18,900	$24,200	$13,200	$17,900	$8,100	$13,400	$6,100	$5,400	$19,000	$17,500	$8,300
99	$22,500	$43,000	$31,200	$37,300	$22,600	$26,800	$13,300	$20,800	$11,800	$10,800	$30,500	$27,300	$14,700

TABLE 3.13 (cont'd)
ONTARIO RAP MUNICIPALITIES
CAPITAL COST SUMMARY
PER UNIT EFFECTIVE COMBINED AREA
SATELLITE TREATMENT AND STORAGE

Control Measure	Thunder Bay	Midland	Sarnia	Windsor East	Windsor West	Fort Erie	Niagara Falls	Welland	Hamilton	Toronto	Belleville	Cornwall	TOTAL
Percent Suspended Solids Removal													
20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
30	$0	$0	$0	$0	$0	$0	$600	$0	$0	$0	$0	$0	$0
40	$700	$0	$0	$900	$700	$700	$1,900	$0	$0	$0	$0	$0	$300
50	$5,100	$2,800	$2,900	$4,000	$3,900	$4,000	$3,700	$1,200	$0	$300	$0	$2,800	$1,200
60	$12,900	$6,500	$7,600	$7,900	$8,200	$9,000	$6,000	$3,800	$300	$2,100	$0	$6,700	$3,400
65	$26,900												
70		$11,300	$14,200	$12,900	$15,300	$27,900	$10,100	$7,400	$2,500	$4,400	$2,700	$12,500	
75					$24,200		$16,000						
77					$37,700								
80		$18,400	$27,800	$20,200				$13,700	$5,400	$7,900	$9,600	$27,700	
82			$37,200										
85								$25,000					
90		$36,100		$38,300					$11,000	$21,200	$27,600		
92									$14,300				
94									$22,100				

Comparison with the central treatment-storage case shows very considerable economies produced by the application of satellite treatment and storage when considering volumetric control. For example, the benchmark control definitions 90 percent volumetric control and one annual flow are estimated to cost approximately $108 million and $439 million respectively, which are one-quarter to one-fifth of the costs required with central treatment and storage. However, it must be pointed out that although volumetric control may be equivalent in these cases, pollutant control may not be. In this case, satellite treatment facilities do not provide the same level of suspended solids control as central treatment facilities.

Section 4
SUMMARY

4.1 SUMMARY OF RESULTS

The study results presented in Section 3 are most important as a means to compare levels of control and costs of control technologies for various municipalities. Such comparison is possible because these results have been developed under a set of assumptions which apply to all municipalities. However, it is important to point out that these results should not be interpreted out of context. For example, costs for a specific level of control for a specific municipality should be accurate with an order of magnitude, but are best interpreted only in comparison to another municipality, rather than as a firm cost estimate for that municipality. The need for the detailed analysis which is conducted as part of a PCP CSO study in order to develop CSO control cost estimates cannot be over-emphasized. Even at that, the cost estimates generated at the PCP level are sufficient only for municipal budgetary purposes, and detailed engineering cost estimates are one step beyond the PCP stage.

The general conclusions which may be drawn from these results are:

1. CSO control costs escalate sharply (diminishing returns to scale) at higher levels of control such as 95 percent volumetric control or 1 overflow event annually.

2. Aggregate costs for higher levels of control are not significantly affected by existing levels of control.

3. The use of satellite treatment in combination with storage facilities is generally more cost-effective than storage facilities in combination with expansion of central treatment, especially with regard to volumetric control. In the case of pollutant control, the cost effectiveness of satellite treatment will be tempered by the relative pollutant removal efficiencies of satellite and central treatment. For example, in this study the control of suspended solids suffers under satellite treatment even though the volumetric control achieved may be equivalent.

4. The removal of suspended solids through any control strategy is limited by the treatment efficiency of the WPCP. This conclusion does not hold for fecal coliforms where removal efficiencies of 99.99 percent are achieved at both satellite and central treatment facilities, but will hold true for any other pollutant with limited removal at the central treatment facility (WPCP).

5. Unit area costs are reasonably uniform across all municipalities for both storage with central treatment and storage with satellite treatment. Typical costs for storage with central treatment range from $10,000 to $30,000 per hectare of

effective combined sewer area for 90 percent volumetric control. For storage with satellite treatment, corresponding costs are $2,000 to $6,000 per hectare. Once again, these cost advantages exist when considering volumetric control, but may not be as dramatic when considering pollutant control.

6. Consideration should be given to all the control criteria used in this study. For example, for the satellite treatment/storage option, examination of percent volumetric control, annual number of overflows and percent fecal coliform removal (high treatment efficiency) all indicated balanced control strategies comprised of storage and treatment. Examination of percent pollutant control, however, where treatment efficiencies are lower, indicated that storage alone is often the preferred solution.

4.2. RECOMMENDATIONS FOR FURTHER MODEL DEVELOPMENT

Limited information on the accuracy of these model results has been developed. For the two case studies examined, the costs estimated to achieve one overflow event per year by the modified EXSUDS model differ from those estimated by the detailed analysis of the PCP by approximately plus-or-minus 30 percent. In general, however, results are expected to be accurate only within an order-of-magnitude.

This modified use of the EXSUDS program is at a developmental stage only, and many improvements may be possible with further effort. Such efforts should include:

1. More case study analysis to compare the results of PCP modelling using STORM for individual sewer catchments with results using the modified EXSUDS model developed here and an aggregate catchment. This will provide a better understanding of model accuracy across a range of variables including:

   - Rainfall characteristics
   - Catchment characteristics such as area and runoff coefficient
   - Drainage system characteristics such as flow regulator capacity.

2. Further development of cost equations to account for the fact that economies of scale are not realized in constructing a number of smaller satellite treatment facilities as compared to constructing one large facility as assumed here.

APPENDIX A

References

Appendix A
REFERENCES

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